TOWARDS A COMMERCIAL FUTURE:
ETHANOL

METHANOL
AS ALTERNATIVE TRANSPORTATION FUELS

Michelle Heath

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ETHANOL & METHANOL AS ALTERNATIVE TRANSPORTATION FUELS

MICHELLE HEATH

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Preface

This study, initiated in February 1988 and completed in November of the same year, arose from a decision by the Canadian Energy Research Institute Board of Directors to assess the potential of ethanol and methanol as alternative fuel sources in Canada. Though Canada is rich in heavy crude oil and bitumen, conventional light crude oil production continues to decline as the productive capacity from reserves additions becomes insufficient to replace the current level of production. Although the recent oil find in British Columbia may serve to enhance our conventional reserve life and the current slump in crude oil prices may render untenable any investment made or contemplated in the use of alternative fuel sources, political instability in the Middle East, which contains the bulk of the world's conventional oil supplies, suggests a definite need to evaluate secure alternative fuel sources for Canadians.

The author wishes to express her gratitude to the five-member advisory committee from Canadian industry and provincial and federal governments for the direction and insights provided in the course of this study. Special thanks must also be extended to the many experts in industry and government who so willingly shared of their knowledge and time, without which this study could not have been completed.

A number of the author's colleagues at the Institute assisted at various stages of the project. Particular thanks are due to Robert Wise who provided substantial research assistance as well as programming and computer support. The graphics were developed by Vance Lickiss, and Janice Morrison and Michele Irvin processed the interim drafts and final manuscript. Thanks are also due to Zaytoon Janjua and Wendy Faid of the I. N. McKinnon Memorial Library who gathered much of the available resource material from across the continent. Dr. Gerry Angevine, Anthony Reinsch and Morgan MacRae of the Institute provided their support and guidance throughout the project.

Chapter 1

INTRODUCTION

1.1 A Review of the History of Energy Sources and Uses in Canada

Renewable resources have played a major role in Canada's evolutionary development. Through each stage of enhancement there has been a demand for fuel sources which would be reliable, economical and convenient. An added requirement today is that the fuel be environmentally safe. Originally biomass was the major energy source for Canadians; however, as the country developed, this dependence on biomass was gradually replaced by coal, then oil, natural gas and electricity (see Figure 1.1).

About 90 percent of Canada's energy supplies at the time of Confederation came from wood. By the 1920s, coal and coke dominated all other forms of energy consumed by Canadians. Even in 1950 these two sources supplied half of the energy used in Canada, although by this time petroleum and natural gas were responsible for over 30 percent of the energy market. By 1960, petroleum and natural gas supplied over half the energy use in Canada; however, as in most industrialized countries, reliance on oil has been decreasing due to conservation, energy efficiency efforts and use of other fuels. By 1986, only 36 percent of Canada's energy consumption was provided by oil.[1]

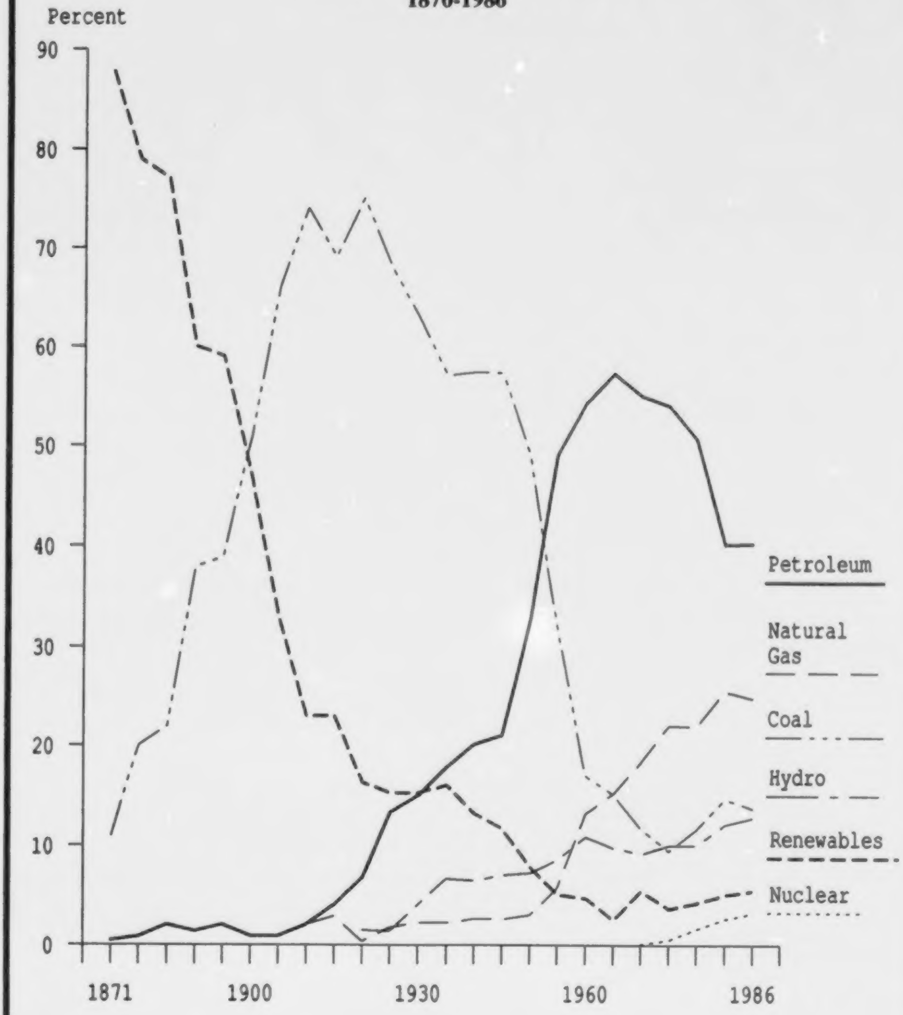
Despite Canada's decreasing reliance on petroleum, it remains not only the primary form of energy being used today, but also the base from which many synthetic polymers for plastics and pharmaceuticals are derived. As Canada's light crude oil supplies are declining, it is important that our petroleum reserves be managed with concern for the future. To the extent that alternative and renewable forms of energy are environmentally acceptable and economically and commercially available to Canadians, their applications should be fully examined.

1.2 Uncertainties Related to Future Sources of Energy

Neither Canada nor the world will run out of petroleum for many decades but as indicated historically, we do not have to run out to be faced with shortage problems. Political instability in the Middle East, which

Figure 1.1

Primary Energy by Source, Canada
1870-1986



SOURCE: Energy Mines and Resources Canada, Energy in Canada: A Background Paper, November 1987.

contains the bulk of the world's conventional petroleum supplies, could again trigger an oil crisis similar to those experienced in 1973 and 1979.

There are factors closer to home affecting our energy supply sources as well. Though Canada is rich in heavy crude oil and bitumen, conventional light crude oil production in Canada will continue to decline in future years as the productive capacity from reserves additions becomes insufficient to replace production. Over this same time period, the market demand for petroleum products will continue to shift to a lighter mix of gasolines, jet and diesel fuels. As indicated by the National Energy Board (NEB) staff report released in 1986, if prices remain low, by the mid-1990s Canada will become strategically dependent on light oil imports (see Figure 1.2).[2]

The transportation sector is almost totally dependent on petroleum. Petroleum resources are finite. They are being steadily depleted while at the same time being subject to increasing demand. It is this knowledge which suggests the potential for building heavy oil upgraders, expanding frontier resources and developing alternative transportation fuels.

1.3 The Effect of Changing Crude Oil Prices on the Market For Alternative Transportation Fuels

There are a number of catalysts that affect the market for alternative transportation fuels. Oil price is one of them. As early as the 1920s, "gasohol" (a gasoline and ethanol mixture) was popular in the United States as a farm fuel,[3] but that was before petroleum-based gasoline became readily available. Since gasoline could be produced more cheaply than the alcohol fuels, they were forgotten as fuel sources until the dramatic price increases of the 1970s. Once again the question of alcohols as alternative fuel sources became of interest to the consumer; could they realistically extend the petroleum fuels or even replace them?

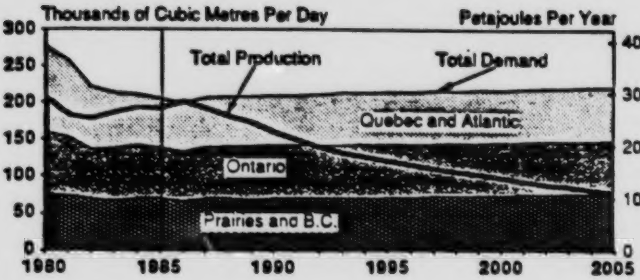
An oil price collapse in Canada would render untenable any investments made or contemplated in the use of alternative fuels. When crude prices are low or on the downturn, as in 1986 when Saudi Arabia tried to recapture its market share by offering to undercut the prevailing oil prices, alternative fuels become a topic to set on the backburner until the next oil crisis. However, when crude prices increase, there is a renewed interest in more secure fuel sources and the potential for alternative fuels once again becomes a viable topic.

It is a topic only, though, because historical development has indicated a down side to high crude prices in the development of alternative transportation fuels. In June 1975, when the Petroleum Administration Act

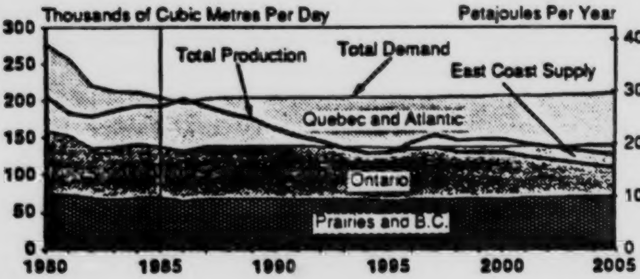
Figure 1.2

Supply and Demand - Light Crude Oil

Low Price Case



High Price Case



SOURCE: National Energy Board, Canadian Energy: Supply and Demand 1985-2005 (Ottawa: Supply and Services Canada, 1986), p. 93.

adopted what has been termed the "high price scenario" for oil and gas production (which was largely unrelated to cost) and natural gas prices were tied to those for crude oil at Toronto, prices escalated.

At the time the high price scenario (which saw prices reaching $27.00 (U.S.) per barrel in the 1990s) was initiated, it was thought that it might stimulate the emergence of new energy alternatives. This did not happen, however. Investors have not been anxious to become involved in a situation where a lower cost commodity--crude oil--is replaced by a higher cost one with greater uncertainties attached--alternative fuels. Because our energy sector has been largely supported by private sector investors whose main objective is profitability, the development of alcohol fuels has not been sparked. Lower crude oil prices have been met by government intervention through various incentives designed to bolster the cash flow of producers of non-renewables, thus further deterring private sector participation in the development of renewable energy alternatives.

It is the crude oil price "shocks" and the emerging public and political will for cleaner burning fuels, more than depleting oil reserves, which tend to focus interest on the viability of developing alternative transportation fuels.

1.4 Environmental Concerns and Regulatory Changes That Will Affect Transportation Fuel Requirements

Environmental concerns are becoming an important issue in Canada. A noted highlight presented in the Energy Options report released by the Honourable Marcel Masse, the Canadian Minister of Energy, in August 1988 stated, "Environmental goals should be accorded the same importance as other economic and social goals in the planning, development and use of energy."[4]

The federal government announced in 1986 that by the end of 1992, tetraethyl lead must be phased out of our gasoline. However, on September 13, 1988 the Canadian Minister of Environment, the Honourable Tom McMillan advanced the deadline for the elimination of lead from gasoline to December 1, 1990. Mr. McMillan stated, "Health data provides compelling evidence that leaded gasoline should be eliminated sooner than originally planned."[5] If tetraethyl lead is no longer used as an octane enhancer in gasoline, other octane sources will have to be found. Canadian oil refiners, being forced to make changes to their operations to compensate for the loss of octane in their product, have two main options to match fuel octane to engine compression ratios:

(i) more severe refining of petroleum fuels, converting low octane hydrocarbon molecules into differently structured but chemically similar molecules with higher octane values by reformation, alkylation and isomerization (PACE, 1985); and[6]

(ii) the addition of high octane chemicals such as oxygenates or aromatics (benzene, toluene and xylene).

In considering these options, the refiner will have to consider the economics, the marketability of the product, the effects on existing vehicles, as well as the environmental impacts of such changes.

The acceptance level for carbon monoxide (CO) in Canada is 13 parts per million (ppm), whereas the United States restricts CO levels to 9 ppm.[7] Although varying socio-economic conditions may be part of the explanation for the differences in standards, another reason arises from the fact that Canada has a large land mass and a relatively small population so it is assumed that Canadians will not encounter the problems facing many of the major U.S. urban centres. The fact is, however, that a major portion of the population in Canada resides in urban areas, which might suggest taking a second look at the allowable carbon monoxide emission levels in Canadian cities.

Both Colorado and Arizona have mandated the use of oxygenated fuels over the winter season. By requiring a minimum oxygen content of 1.5 percent by weight during January and February of this year, Colorado's Oxygenated Fuels Program resulted in an 8 to 11 percent reduction in carbon monoxide levels. For instance, in downtown Denver the monitoring station registered a reduction of 9.36 percent. In future years, Colorado's program will be effective November 1 through March 1 with a 2 percent minimum oxygen content requirement.

Another environmental concern emanating from fossil fuel combustion and currently under consideration in Canada is the "greenhouse effect," created when gases such as CO_2 and chlorofluorcarbons (CFC's) absorb some of the sun's infrared rays, trapping them in the atmosphere and warming the earth. Scientists fear the long-term effects of this may seriously affect our very existence. Perhaps the leaning effect of oxygenates would provide a partial solution to this problem. Following the recent international conference on "The Changing Environment - Implications for Global Security", a Task Force on Energy and the Environment was established to review the effects of CO_2 emissions in Canada.

1.5 The Detrimental Effects of Metallic Octane Enhancement on the Environment

1.5.1 Lead in Gasoline

Lead is a heavy, non-degradable metal which, in the usual form of tetraethyl lead, has been used as an octane-enhancer and anti-knock agent in gasoline for over 60 years. Virtually all the lead added to gasoline is eventually released back into the atmosphere[8] and is known to have extremely serious effects on the human nervous system. For many years it has been recognized as highly toxic through ingestion, inhalation or skin absorption. It is known to cause learning disabilities in children and high blood pressure in adults.[9]

1.5.2 MMT

Methylcyclopentadienyl manganese tricarbonyl (MMT) is an anti-knock agent in unleaded gasoline. It is currently allowed as an octane enhancer in all gasolines in Canada but is prohibited in unleaded fuel in the United States. Although MMT was believed to interfere with the effective reduction of exhaust emissions in older vehicles (1970s and older), this does not appear to be the case with current vehicle technology. Though MMT is highly toxic in its pure form and therefore requires stringent safety guidelines at all stages of manufacturing, transportation and blending with gasoline, a recent study undertaken by the Canadian General Standards Board found the quantities of MMT allowed in Canadian fuels (0.072 grams/litre; 0.018 grams of manganese/litre) were not considered harmful to the environment or human health.

1.6 Objective of the Study

Among the alternative transportation fuels more frequently discussed today are ethanol and methanol. The objective of this study is to review, on the basis of available information, recent developments in the Canadian gasoline markets and to examine the likely developments in sourcing, pricing and competition for these alcohol fuels, in relation to each other and to gasoline in the regional markets.

The study is organized as follows. Chapter 2 discusses the advantages and disadvantages of six oxygenates which have been considered as fuel additives for octane enhancement in Canada as well as their use to date. Following this is a discussion regarding the oxygenates of choice for this study and the standards they may have to abide by in order to be competitive alternative fuels for Canada. In Chapter 3, the value of ethanol to the Canadian transportation system as an octane enhancer is developed. The chapter concludes with a suggestion as to how the long-run prospects for ethanol use in Canada may ultimately be determined. Chapter 4 discusses the dilemma facing this country's methanol producers and considers the benefits of substituting methanol for diesel fuels with the aim of providing both an alternative fuel source as well as a cleaner environment. Chapter 5 discusses the implications of using ethanol and methanol as alternative fuel sources for the stakeholders involved and suggests the necessary pre-steps which will be required in order to maintain harmony between all the players affected by this industry.

Footnotes

[1] Bio-joule, "Why Oxygenated Transportation Fuels?" A summary of a statement presented by the Honourable Marcel Masse, Minister of Energy, Mines and Resources Canada to the Standing Committee on Energy, Mines and Resources in Ottawa on May 11, 1988 (Winnipeg: September 1988).

[2] National Energy Board, Canadian Energy Supply and Demand: 1985-2005 (Ottawa: Supply and Services Canada, October 1986).

[3] Energy, Mines and Resources Canada, Future Transportation Fuels, Alcohol Fuels (Ottawa: Department of Supply and Services, 1986) p. 5.

[4] Energy, Mines and Resources Canada, Energy and Canadians Into the 21st Century, Cat. No. M27-89/1988-1 (Ottawa: Ministry of Supply and Services, 1988), p. 14.

[5] Environment Canada, Federal Government Advances Deadline For Elimination of Leaded Gasoline By Two Years, News Release, PR-HQ-088-54 (Ottawa: September 13, 1988), p. 2.

[6] The Royal Society of Canada, Lead In Gasoline, Alternatives to Lead in Gasoline (Ottawa: The Commission on Lead in the Environment, February 1986), p. 1.

[7] Canada's carbon monoxide levels are tied to the level of exposure over an 8 hour period. According to Environment Canada, the three defined levels for CO are:

(i) tolerable at 17.4 ppm
(ii) acceptable at 13 ppm
(iii) desirable at 5 ppm

The United States has established 9 ppm as its enforceable primary quality objective.

[8] Organization for Economic Co-operation and Development, Environmental Effects of Automotive Transportation, The OECD Compass Project (Paris, France: OECD Publications Service, 1986).

[9] It is interesting to note that the Eighth Edition of The Canadian Chemical Dictionary revised by Gessner G. Howley and copyrighted in 1971 states tetraethyl lead (TEL), a colourless, oily liquid with a pleasant odor, is "a major pollutant" and attaches a note at the bottom of its description stating "TEL and other lead compounds will be discontinued as an automotive gasoline additive because of air pollution by 1974 or sooner."

Chapter 2

OXYGENATED FUELS

2.1 Introduction

Lead phaseout and an increasing demand for premium unleaded gasoline are resulting in the need for increased octane requirements. Refineries are quite distinct from each other in their flexibility to improve their current streams entering the gasoline pool; while "high severity reforming" or "isomerization" may be the answer to some refiners, "oxygenates" may provide a more viable option for others.

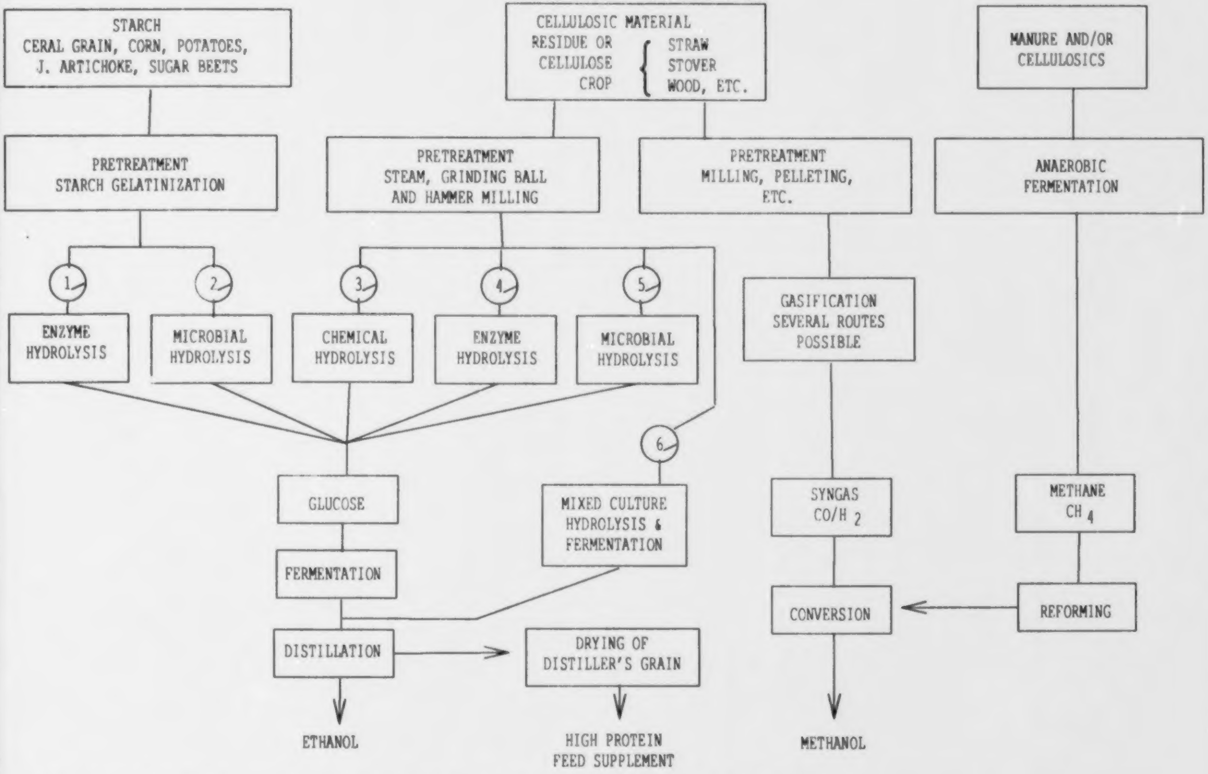
When oxygen-containing compounds such as alcohols or ethers are added to gasoline in small amounts, a blend known as "oxygenated gasoline" results. Since oxygenates are beneficial in boosting the octane rating or antiknock characteristics of the fuel, they represent one alternative to lead. They also displace a portion of the crude oil required in the manufacture of gasoline, which may prove significant in the near future if the domestic supply of conventional light crude oil continues to decline.

There are six oxygenates that have been considered as fuel additives in Canada: methanol and ethanol, which are the simplest alcohols; isopropyl alcohol (IPA); isobutyl alcohol (IBA) and tertiary butyl alcohol (TBA), which are more complex alcohols; and an ether, methyl tertiary butyl ether (MTBE).

Methanol (CH_3OH or MeOH), otherwise known as methyl or "wood" alcohol, is a fuel source that can be manufactured through several processes from almost any energy source (see Figure 2.1). Coal, oil, peat, wood, grass crops and even organic wastes can be processed into MeOH. In Canada, however, methanol is made entirely from natural gas. There are three world-scale plants that currently produce methanol in Canada: Celanese Canada, based in Edmonton, Alberta; Alberta Gas Chemicals Ltd. in Medicine Hat, Alberta; and Ocelot Industries Ltd. in Kitimat, B.C.

Ethanol (C_2H_5OH), also called ethyl or "grain" alcohol, can be derived from ethylene, a product of oil refining; from ethane, a constituent of natural gas; or from fermentable sugars, derived from typical sugar or starch crops, cellulosics, and other forms of biomass. Enzymes assist in the conversion of starches to sugars, which are then converted to ethanol through a fermentation process. At the moment, the ethanol supply dedicated to the

Figure 2.1
Routes for Liquid Fuel Production from Biomass


STARCH
CERAL GRAIN, CORN, POTATOES, J. ARTICHOKE, SUGAR BEETS
CELLULOSIC MATERIAL
RESIDUE OR CELLULOSE CROP
STRAW
STOVER
WOOD, ETC.
MANURE AND/OR CELLULOSICS
PRETREATMENT STARCH GELATINIZATION
PRETREATMENT STEAM, GRINDING BALL AND HAMMER MILLING
PRETREATMENT MILLING, PELLETING, ETC.
ANAEROBIC FERMENTATION
1
2
3
4
5
ENZYME HYDROLYSIS
MICROBIAL HYDROLYSIS
CHEMICAL HYDROLYSIS
ENZYME HYDROLYSIS
MICROBIAL HYDROLYSIS
GASIFICATION SEVERAL ROUTES POSSIBLE
6
GLUCOSE
MIXED CULTURE HYDROLYSIS & FERMENTATION
SYNGAS CO/H 2
METHANE CH 4
FERMENTATION
CONVERSION
REFORMING
DISTILLATION
DRYING OF DISTILLER'S GRAIN
ETHANOL
HIGH PROTEIN FEED SUPPLEMENT
METHANOL

SOURCE: Agriculture Canada, Alcohol Fuels From Agriculture - Discussion Paper, January 1980, p. 24.

transportation industry in Canada is quite limited. Mohawk Oil produces about 8 million litres of ethanol per year from cereal grains at its distillery in Minnedosa, Manitoba.

Isopropyl alcohol (IPA), derived from treating propylene with sulphuric acid and hydrolyzing, is an octane enhancer as well as a methanol cosolvent in motor gasoline blends. Although Shell Canada produces about 100 million litres per year from its Sarnia, Ontario plant, only about half is available for fuel use.[1] At the moment, it is being sold as a cosolvent with methanol in Ontario's "V-Plus" service stations; however, a much larger supply would be necessary if isopropyl alcohol were to gain any further use as a blending agent in gasoline.

Isobutyl alcohol (IBA) is an octane enhancer which has also been used as a methanol cosolvent in motor gasoline blends. IBA is a by-product of the manufacture of special chemicals used in the plastics industries. BASF Canada Inc. had been producing up to 30 million litres of IBA per year in Montreal, but in early 1986 the plant was deemed uneconomical and was shut down. Methanol gasoline blends using IBA have since been forced to utilize other cosolvents such as IPA.

Tertiary butyl alcohol (TBA), produced almost entirely as a by-product of propylene oxide manufacture, can also be made from isobutylene hydration. Atlantic Richfield Company (ARCO), the world's largest producer of TBA, until recently marketed a blend known as "Oxinol" which contained methanol and TBA in equal proportions (4.75, 4.75). Although ARCO continues to market this product in Europe, the company no longer markets Oxinol in the U.S. ARCO sold its Oxinol stations to Atlantic Refining Company which in turn discontinued Oxinol in favour of an MTBE blend.

Methyl tertiary butyl ether (MTBE) is produced by reacting methanol with isobutylene. Isobutylene, which is in short supply in Canada, is in turn obtained by the fractionation of by-product refinery gases produced from the cracking of crude petroleum. Although isobutylene is a refinery by-product, it is not being produced on a large enough scale in Canada at this time to support an MTBE industry. Canada's surplus butane, however, which is presently being exported, could be converted to isobutane. The isobutane could be used to produce isobutylene which, when combined with methanol, produces MTBE. Such a process would add about 5 cents per litre to the cost of MTBE.[2]

2.2 Oxygenates of Choice for this Study

Ethanol and methanol are alcohol fuels commanding considerable attention in the Canadian energy market for a number of reasons. With tetraethyl lead being phased out of Canadian gasoline by 1990, "with a very limited list of exceptions for critical commercial, farm or marine equipment that require minimum levels of lead to avoid premature engine failure,"[3] refiners will be in need of a long-term, low-cost source of octane. Ethanol and methanol are high performance, high octane transportation fuels which are not new to the Canadian fuel market. Mixed with gasoline, these alcohols increase the octane value of the fuel, while in concentrated form they permit an increase in the engine compression ratio to the order of 13:1, thus providing greater power.[4]

Given these potential applications and benefits, it is timely to establish an understanding of what an alcohol fuel industry may or may not be able to do for the shareholders in Canada's fuel industry: the fuel supplier, the vehicle supplier, the motorist, the government and, in this case, the agriculture industry.

Ethanol has been used as a fuel in various countries throughout the world, always during times of agricultural or national emergencies and always when crude prices were at peak levels. If ethanol can be produced and proven beneficial during times of strife, then there would appear to be potential for providing capital for the development of this technology to the point where the price of ethanol is comparable with the current price of gasoline, thus avoiding the costly exercise of "throwing" an industry together during a future recession or energy crisis. As it is, Canada's farmers have until recently been faced with extremely low average grain prices and domestic refiners will soon require new octane sources as lead is phased out of our fuel supplies. It seems, therefore, a reasonable time in Canada's history to establish the potential value of ethanol.

Current technology suggests that the feedstock requirements of an ethanol industry may provide markets for Canada's higher grade grains as well as utilize the poorer grades which are more difficult to sell in the domestic and world marketplace. Until the recent drought in Canada which resulted in an upward swing in grain prices, Canada's farmers had been faced with extremely low returns on their crops. Many of the countries which once imported Canadian grains and grain products have become self-sufficient and, in some cases, have established their own export programs. As the markets for our cereal grains decreased, so also did their prices, leaving the Canadian agricultural community in serious need of further subsidies to support it. An ethanol industry could well prove beneficial in providing markets for Canadian grain farmers; however, the latest upward price fluctuation has once again increased uncertainty regarding medium- to long-term grain price trends.

With respect to methanol, Canadian producers manufacture sufficient supplies to meet the current domestic demand and export 85 percent of their production to the United States and other countries.[5] However, international competition in the market may threaten this arrangement. Saudi Arabian gas sources, for example, are becoming highly competitive in producing and transporting methanol to markets such as the U.S. It would appear to be beneficial and perhaps prudent, therefore, to expand our domestic market for methanol. Expanded use of methanol for domestic transportation purposes would obviously ensure a larger market for our methanol producers.

Why ethanol and methanol? If these products can be developed in a fashion that will not only satisfy transportation fuel standards but be competitive with gasoline, it could prove very beneficial to the Canadian oil refiners, the ethanol and methanol producers as well as the farmers. More importantly for the long term, it could contribute to energy self-sufficiency in Canada, while providing diversification opportunities in certain regions, as well as lower carbon monoxide pollution levels.

Obviously, not all the players would be affected equally or even favourably. Each stakeholder would approach the new industry from his own perspective, thus recognizing various other opportunities and being willing to accept different risks. This study will objectively examine each of the alcohol fuels chosen, recognizing that if a new fuel is to become a viable substitute for an existing one, it must be readily available, competitively priced and offer comparable performance.

2.3 Use in Canada and Other Countries

2.3.1 Canada

Although Canada is only at the research, development and demonstration stage of an oxygenated fuel industry, commercial marketing of alcohol fuels is not new to the Canadian marketplace.

As mentioned earlier, Mohawk Oil Co. Ltd. produces approximately 8 million litres annually of ethanol from the fermentation of wheat at a converted distillery in Minnedosa, Manitoba. In 1981, when Mohawk began marketing "gasohol" (10 percent ethanol in gasoline) in Manitoba, the provincial government provided a gasohol tax exemption. The exemption, which had originated in May 1980, was originally set to the full amount of the gasoline tax. In the early 1980s this tax was ad valorem, based on a retail price averaging formula. By the time Mohawk's Minnedosa plant began producing, the exemption had risen to 5.7 cents per litre. The original intention was to phase out the exemption over 3 or 4 years. It has since been altered to allow only the alcohol content to be exempt from the gasoline tax; therefore, it is currently fixed at 2.5 cents per litre for gasohol.

The economic benefits to Minnedosa have been obvious. The plant not only provides jobs at the distillery, but also an assured market for the feed wheat produced by local farmers. As well, the stillage produced as a by-product is used to feed cattle in the area. This experimental project by Mohawk Oil most likely saved the town from economic decline after the original distillery shut down in 1972. It has also been a good indication that alcohol fuel can do more than simply provide an alternative fuel source.

In 1984, Mohawk expanded its alcohol fuel market into Saskatchewan and in 1985, into Alberta and B.C. In these provinces they marketed until recently an M5E3 blend (5 percent methanol, 3 percent ethanol, 92 percent unleaded gasoline) called "EM Unleaded." Alberta Gas Chemicals provided the methanol for this blend and whatever ethanol could not be obtained from the Minnedosa plant was purchased from Commercial Alcohols Ltd. in Montreal. Recently Mohawk began marketing a new blend, "Premium Plus" (5 percent ethanol and 95 percent unleaded gasoline), in place of the M5E3 blend. Mohawk's penetration of the alcohol fuel market has been increasing, which would indicate a positive response by the motoring public to its concept of blended alcohol fuels.[6]

Canadian Methanol Canadian (CMC) of Winnipeg, a company which began marketing a methanol-gasoline blend through 3 Domo service stations, and later marketed a 5 percent methanol and IBA blend at 14 Pioneer service stations in Southern Ontario, has since backed out of the alcohol fuel market. As it was neither a methanol nor IBA producer, it bore the full product, blending and transportation costs of the blends and, with current depressed oil prices, found the project uneconomical.

Alberta Gas Chemicals Ltd. and Suncor Inc. have, since May 1985, marketed a blend of 4.75 percent methanol, 4.75 percent isopropanol and 90.5 percent unleaded gasoline through the V-Plus service stations in Ontario, which were purchased by Alberta Gas Chemicals with the intention of promoting methanol-gasoline blends in Canada. Another alcohol blend new to the Ontario fuel market is Ethanol Plus (4.3 percent methanol, 2.1 percent ethanol and 1.6 percent isopropyl alcohol). This low level alcohol blend was developed by Ontario's Co-operatives and Alberta Gas Chemicals. It is blended by SUNOCO.

There is another project which, despite not involving the actual marketing of alcohol fuels, will help to determine the value of methanol when used in large engines. The Methanol In Large Engines (MILE) Program is designed to test the use of 100 percent methanol in heavy duty truck and bus diesel engines in both large and small urban centers across Canada.[7]

Canada is not the only country considering the encouragement of fuels which are not petroleum based. As stated earlier, petroleum is a non-renewable energy source which is gradually being depleted. Sharp price increases have and may again in the future occur due to political unrest in various parts of the world. The result of these factors is that "energy" and "oil security" have become significant public policy issues in many countries of the world. Standards for lead content and other particulate matter in gasolines are also changing in many countries as the issue of pollution from exhaust fumes becomes of great concern (see Table 2.1). It is understandable, therefore, why alcohol and oxygenated fuels are emerging as major candidates in the running to replace a portion of the petroleum supply for the transportation sector. The following section offers a brief look at some of the countries becoming more prominent in developing alcohols as alternative transportation fuels.

2.3.2 United States

Importation of oil accounted for 24 percent of the U.S. trade deficit in the first half of 1987.[8] The U.S. is seeking security of energy supplies, essential to its economic life, and will continue to strive toward this goal until it acquires access to adequate fuel resources at competitive costs.

The United States Department of Energy has recognized the potential for both ethanol and methanol as transportation fuels. American fossil fuel resources are rapidly declining and there is great concern with the pollution problems. As lead is being phased out of U.S. gasoline products, alcohols may be in higher demand as octane boosters. The U.S. already has the necessary elements for a fuel-supply infrastructure, as both these alcohols have been used extensively in their chemical industry. Also, low level blends of gasoline with ethanol and methanol have already been sold in the marketplace.

Presently, ethanol accounts for almost all the alcohol being blended into unleaded gasoline in the U.S. and, yet, relative to their total energy requirements in the transportation sector (9.8 million barrels per day (U.S.)

TABLE 2.1

SAMPLE LEAD IN GASOLINE STANDARDS IN VARIOUS COUNTRIES

(various years)

Country	Year	(g/1) Standard[a]	Comment
EEC	1978	0.40	Maximum
		0.15	Minimum
	1989	0.15	Maximum leaded
		0.01	Maximum unleaded, to be widely available
Australia	1983[b]	0.4-0.8	
	1986		No lead for new cars
Canada	1981	0.013	Unleaded
		0.77	Leaded
	1987	0.29	Leaded
Finland	1981	0.40	Maximum for premium
	1985	0.15-0.40	Maximum for premium
	1986	0.15	
France	1983[b]	0.40	
Germany	1972	0.4	
	1976	0.15	
	1986	0.026	Leaded gasoline only
	1995	0.0	
Greece	1966	0.84	
	1981	0.40	
Italy	1964	0.635	For premium gasoline
	1967	0.635	For regular gasoline
	1981	0.4	
Japan	1983[b]	0.13	For premium gasoline
		0.02	For regular unleaded gasoline
New Zealand	1983[b]	0.84	
	1986	0.45	
	1990	0.0	Unleaded regular to replace leaded regular
Sweden	1978	0.15	
	1986	0.0	
Switzerland	1982	0.15	
	1985	0.013	For regular unleaded gasoline
	1986		No regular leaded allowed
United Kingdom	pre-1973	0.84	
	1973	0.64	
	1981	0.4	
	1986	0.15	
	1990		No lead for new cars
USA	1973	0.13	Refinery average
	1973	0.013	Unleaded
	1986	0.026	Leaded
	1988	0.013	Possible ban of leaded

SOURCE: Organization For Economic Coordination and Development, *Environmental Effects of Automotive Transport* (Paris: 1986), p. 57.

[a] Unless otherwise indicated, the given standard is the maximum allowable lead concentration for that grade of gasoline.

[b] Standard as of February 1983.

of crude oil equivalent), ethanol provides only 825 million gallons (U.S.) or 0.3 percent of the transportation sector's energy demand (see Table 2.2 and Figure 2.2).[9] Nameplate U.S. fuel-ethanol plant capacity has been increasing but the number of operating plants has declined from peak times. Three out of five fuel-ethanol plants, mainly small farm-scale operations, have shut down primarily for economic reasons.[10]

Currently, all the ethanol being used in U.S. motor fuels is produced by the fermentation of sugars derived from biomass.[11] The major reason for using this process is that only fuel-alcohol produced from biomass is supported by tax exemptions in the U.S. Ethanol blends at the federal level alone qualify for a $0.06 (U.S.) per U.S. gallon tax exemption, which is equivalent to $0.60 (U.S.) per U.S. gallon of pure ethanol.[12] This is equivalent to 20 cents (Cdn.) per litre of ethanol. Many of the states also provide their own tax incentives which range up to 14 cents per gallon or 4.6 cents (Cdn.) per litre.[13] However, it appears that the high cost of ethanol as well as the lack of user familiarity and/or acceptance is still restraining its further utilization in the U.S. marketplace.

"Gasohol," a gasoline blend containing 10 percent ethanol, currently accounts for nearly 8 percent of total U.S. gasoline sales and utilizes 1.5 billion litres of ethanol annually. It has also been estimated that another approximately 15 to 20 percent of total U.S. gasoline sales contain MTBE, or alcohols other than ethanol.[14]

The United States is currently the largest producer of methanol in the world (see Table 2.3).[15] Although the partial oxidation of heavy and light crude oil fractions provides some of the U.S. methanol supply, most is produced through steam reforming of natural gas. The gasification of coal and biomass also holds potential for low-cost methanol production, but at the present time has not been found competitive.

Methanol currently provides 0.09 percent, or 280 million gallons (U.S.), of the transportation sector's annual energy demand. About 95 percent of this methanol is used to make MTBE which in turn provides about 1.2 billion gallons (U.S.) per year of automotive fuel in the form of gasoline blends (see Table 2.4).[16]

Approval must be sought from the U.S. Environmental Protection Agency (EPA) for changes in composition to unleaded gasoline, since it is the responsibility of this agency to determine whether or not the additives, (e.g., oxygenates) will result in unsatisfactory exhaust emissions from vehicles designed for unleaded gasolines. The EPA has so far approved several oxygenated blends. These include blends containing up to 10 percent

TABLE 2.2

U.S. PRODUCTION AND CONSUMPTION OF FUEL ETHANOL

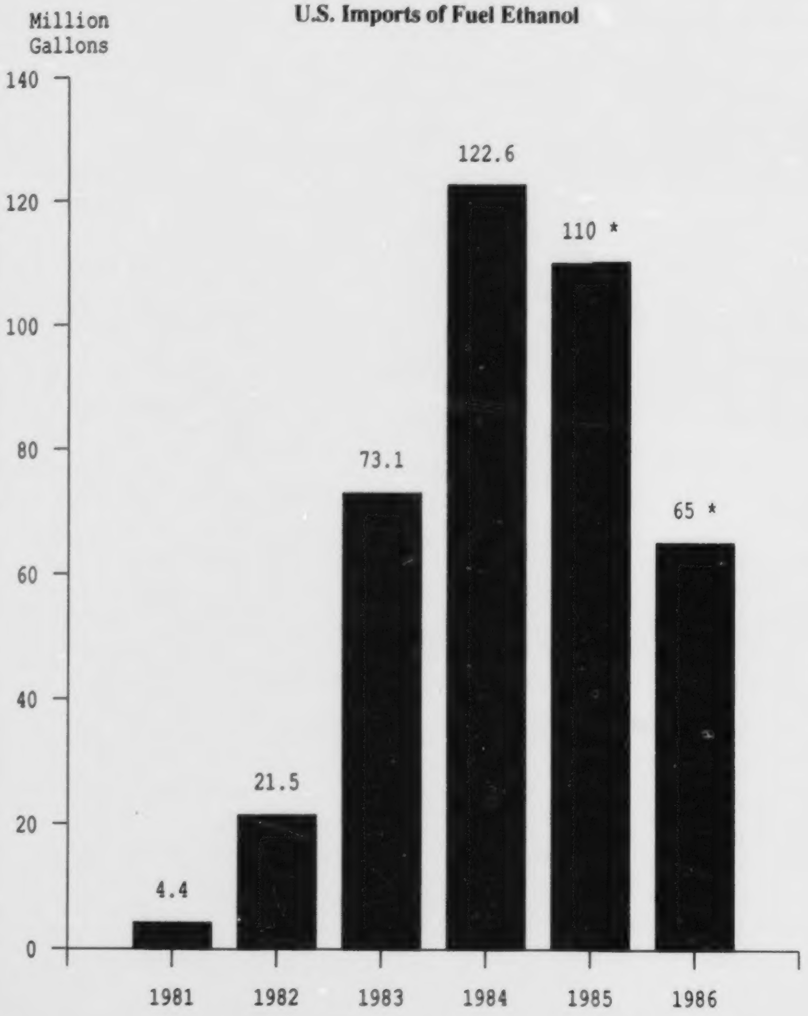
Year	Production (million gallons)	Production Capacity (million gallons/year)	Consumption (million gallons)	Capacity Utilization (percent)
1979	20	60	20[a]	33
1980	40	180	80	22
1981	75	830	85	20
1982	210	595	234	35
1983	375	700	443	54
1984	430	840	567	51
1985	650	975	790	67
1986	750[b]	1,125	825[b]	67

SOURCE: United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One (Washington, D.C.: January 1988), p. B-2.

[a] Estimated.
[b] Projected.

Figure 2.2

U.S. Imports of Fuel Ethanol



* Includes toluene, benzene, and gasoline blends.

SOURCE: U.S. Department of Energy, Assessment of Costs and Benefits of Flexible and Alternate Fuel Use In The U.S. Transportation Sector, Progress Report One, January 1988, p. B-3.

TABLE 2.3

U.S. PRODUCTION OF METHANOL[a]

Year	Production (million gallons)	Capacity (million gallons/year)	Capacity Utilization (percent)
1979	1,111	NA	--
1980	1,079	1,441	75
1981	1,294	1,551	83
1982	1,139	1,585	72
1983	1,204	1,455	83
1984	1,239	1,580[b]	78
1985	760	1,200[c]	63
1986	1,100[d]	NA	--

SOURCE: United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One (Washington, D.C.: January 1988), p. B-6.

[a] Figures include both chemical- and fuel-grade methanol.
[b] Standby and idled capacities not estimated.
[c] Additional 500+ million gallons on standby or idle.
[d] Estimated.

TABLE 2.4

U.S. CONSUMPTION OF METHANOL

	Consumption (million gallons)			
Year	Industry	Fuel	Total	Percent of Total Fuel Consumption
1979	1,090	10	1,100	0.9
1980	1,016	50	1,066	4.6
1981	1,108	86	1,194	7.2
1982	904	120	1,024	11.7
1983	1,000	155	1,155	13.4
1984	1,159	193	1,352	14.2
1985[a]	1,100	170	1,270	13.4
1986	NA	280	NA	--

SOURCE: United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One (Washington, D.C.: January 1988), p. B-5.

[a] Estimated.

ethanol, up to 11 percent MTBE (in September of this year the EPA conditionally granted a waiver for a fuel containing 15 percent MTBE to Sun Refining and Marketing Company), and a few blends of methanol with cosolvents and corrosion inhibitors. The EPA has also approved a blend of 4.75 percent methanol and 4.75 percent TBA in unleaded gasoline (ARCO's "Oxinol") as well as a 5 percent methanol and 2.5 percent cosolvent blend proposed by E.I. du Pont de Nemours and Co. (ethanol being the preferred cosolvent). One blend, "Petrocoal" which received approval and then had the approval revoked, contained 12 percent methanol and 3 percent cosolvent.[17] Certain car manufacturers have suggested that major engine problems could arise at this level of methanol blending.

As referenced in Section 2.1, ARCO Petroleum, as one of the initial marketers of methanol-gasoline, as an oil refiner, as a gasoline retailer, as a methanol producer and as the world's largest manufacturer of TBA, had a vested interest in producing a good alcohol blend. According to the EPA, the "Oxinol" blend was a good product and yet it is no longer being sold in the United States. This may well be due to adverse publicity from a number of automobile manufacturers regarding "engine problems" in current gasoline vehicles using low level methanol blends, plus poor blending techniques by a number of small independent producers which resulted in customer dissatisfaction.

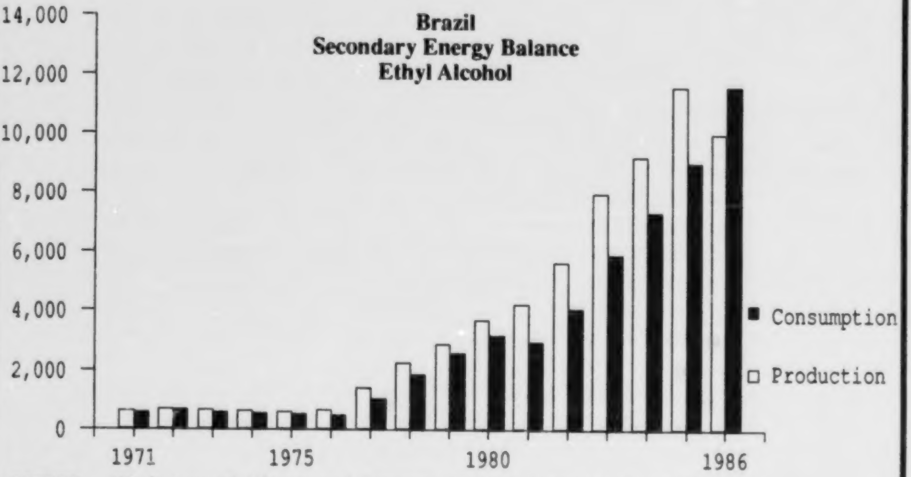
Canadians can and should learn from the knowledge and experience already gathered by the U.S. Environmental Protection Agency. The only way the refiners and the automobile manufacturers will be able to gain customer acceptance of, and confidence in, oxygenated gasolines will be to ensure careful and accurate blending procedures. Unfavourable publicity can have immediate and extremely adverse affects on the oxygenated gasoline market. Further, the success of such a market will require proper fuel specifications for today's engines as well as for the "flexible fuel vehicles" of the future.

2.3.3 Brazil

Brazil, the world's largest producer of ethanol, has developed an aspiring alcohol fuels program (see Figure 2.3).

The oil crises of the 1970s prompted the Brazilian government to recognize the importance of becoming less dependent on expensive foreign oil (see Figure 2.4). As a result Brazil turned to the production of ethanol to reduce their foreign debt, and to ensure themselves of a more stable domestic fuel supply. Another pertinent factor was the need to assure Brazilian farmers of higher prices for their sugar cane. The emergence of an ethanol

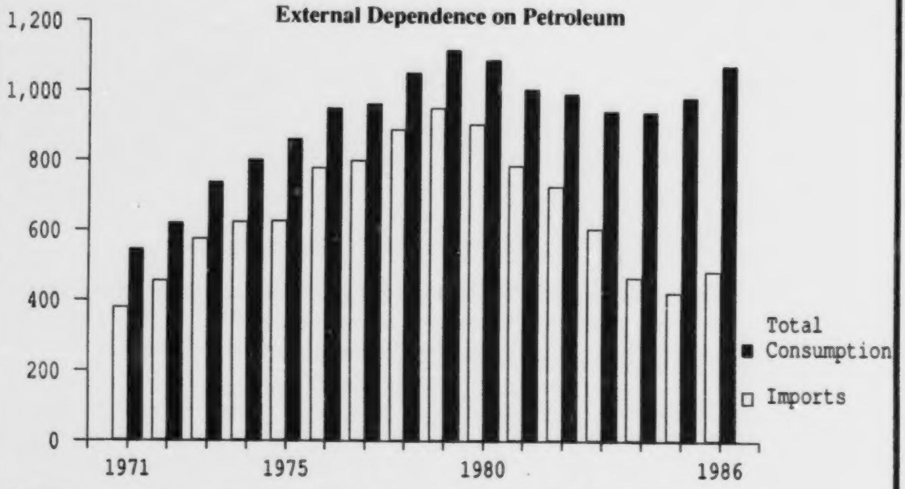
Figure 2.3



Brazil
Secondary Energy Balance
Ethyl Alcohol

SOURCE: Ministry of Mines and Energy, Federal Republic of Brazil National Energy Balance, 1987, p. 24.

Figure 2.4



External Dependence on Petroleum

SOURCE: Ministry of Mines and Energy, Federal Republic of Brazil National Energy Balance, 1987, p. 66.

industry produced other benefits for the Brazilian economy as well; employment opportunities were created in the new ethanol industry and were rejuvenated in the previously declining agricultural industry.

Brazil's production of alcohol fuel was approximately 3 billion gallons (U.S.) in 1986.[18] Government incentives ensured that in 1986, virtually all gasoline sold in Brazil was an "E20" blend. Currently more than 90 percent of all new vehicles sold in Brazil are powered by fuel-ethanol engines and one-third of the vehicles operating are run on 96 percent ethanol and 4 percent water. A small 1-2 litre tank of gasoline is necessary for starting these vehicles, especially for temperatures of 15° centigrade or less. Fuel ethanol has also been used as a diesel fuel in Brazil; however, additives are required to improve the ignition characteristics.[19]

Brazil's PROALCOOL program has not been without problems. The first two phases of the program involved expanding ethanol production and promoting all-ethanol vehicles. Fixing sugar prices and quotas by the National Institute for Sugar and Alcohol on a cost basis, introducing producer credit subsidies which paid up to 75 percent of investment, and government assurance that sugar mills/distilleries would receive 6 percent return on their investment as long as they produced ethanol rather than exported their sugar, ensured the success of phase one.

Phase two, prompted by the 1979 oil price rise and the impact on the country's foreign debt, called for a massive switch to dedicated ethanol vehicles with the aim of reaching 50 percent of vehicle sales by 1985. Lower purchase taxes, lower registration fees, smaller downpayments, tripled repayment periods, and lower fuel costs encouraged customers to buy the new vehicles. Problems occurred when initial sales of ethanol cars and retrofits were so high that Brazilian manufacturers implemented only the minimum modifications required for all ethanol vehicles and authorized mechanics began offering inferior conversions at lower prices. The result was less than optimum efficiency from the cars and consumer dissatisfaction.

Other problems also began emerging. Price controls made it more profitable for some producers to export anhydrous alcohol rather than to supply ethanol (hydrous alcohol) to the domestic market. This resulted in insufficient supplies to meet the automotive demand. Also, when world sugar prices were predicted to rise and the government responded by increasing ethanol pump prices from a low of 40 percent of gasoline prices towards the 65 percent limit and suspending credit subsidies for distillers, sales of ethanol vehicles dropped sharply from 73 percent of all auto sales in December 1980 to 9 percent in July 1981. These problems revealed the program's dependence on extensive government intervention in the market. They also indicate just how quickly consumers react to a change in commitment and prices.

However, with Brazil's massive foreign debt continuing to rise, petroleum supplies remaining uncertain and world sugar prices actually remaining low, the government reassessed its commitment and set about to restore consumer confidence in fuel ethanol. Once again, a number of incentives were established resulting in increased ethanol production, a surge in ethanol vehicle sales and strengthened demand for the product (see Figure 2.5).

Brazil's alternative to ethanol production would be increasing domestic petroleum exploration and exporting sugar. However, domestic oil exploration is expensive and exporting sugar is likely to result in depressing even further the world market sugar price.[20]

Canada is not confronted with the same set of energy problems as Brazil. However, Canadians could benefit a great deal from thoroughly investigating the Brazilian experience. Automotive manufacturers alone could gain a great deal of knowledge regarding the pros and cons of using ethanol in motor vehicles.

2.3.4 West Germany and Austria

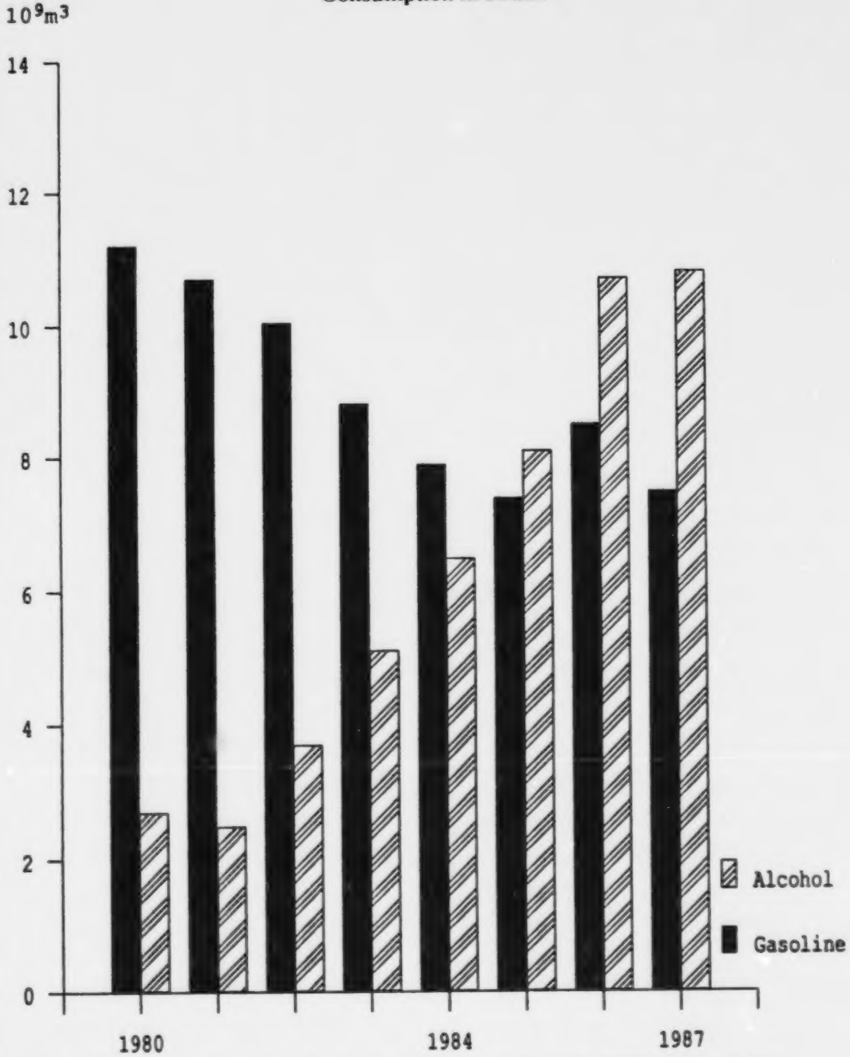
In 1985, 80 percent of all gasoline sold in West Germany contained between 2 and 3 percent methanol with TBA as a cosolvent.[21] West Germany must rely on imported energy sources for much of its transportation requirements. As a result, it has become a leader in the development of alcohol fuel technology, hosting the second of seven International Fuel Technology Symposiums. Spark-ignition systems and diesel engines capable of using fuel-ethanol and fuel-methanol blends have been developed by Volkswagon and Daimler-Benz. Fuel-methanol engines, developed by Deutz and Mann, are currently being tested in heavy duty trucks and buses. Porsche is also contributing to the advancement of oxygenated fuels with their experimental vehicles which can operate using either gasoline or fuel-methanol exclusively.

In Austria, blends of 90 percent domestic gasoline with 3 percent methanol, 2 percent TBA and up to 5 percent MTBE are being marketed.[22] The blending of the oxygenated fuel occurs at Austria's single, state-owned refinery. The remaining demand for gasoline in Austria is met by supplies from West Germany, which also contain methanol and TBA, and from Italy.

From the German and Austrian experiences, Canada should recognize that when governments, oil companies and automotive manufac-

Figure 2.5

Fuel Alcohol and Gasoline Consumption in Brazil



SOURCE: Presentation by R.M. Franke, Seventh Annual CERI Oil and Gas Markets Conference, Calgary, 1988.

turers take a co-operative approach, technical problems arising with the introduction of a new fuel industry can be overcome.

2.3.5 Japan

Japan has extensively addressed the use of "neat alcohol" as well as alcohol blended with both gasoline and diesel fuel. Toyota, Honda, and Nissan have all done comprehensive research and experimentation with methanol as a fuel. Both Toyota and Nissan have agreed to share data with the U.S. EPA on emission characteristics of methanol engines.[23]

2.4 CGSB Standards for Transportation Fuels

The current Canadian General Standards Board (CGSB) specifications for gasoline were set with the refineries well represented on the standards-setting committee. However, Canada does not have a formal standard for oxygenated gasolines, although a preliminary draft has been developed by the CGSB Committee on Gasoline and Alternative Automotive Fuels. The latest draft, published in May 1987, is still under review. Most of the concerned parties in the alternative fuel market have suggested the requirements for gasolines containing alcohols should, as closely as possible, match those of gasoline. One point which is being questioned, though, is whether or not fuel quality would be affected adversely by allowing a slightly higher Reid Vapour Pressure (RVP) for alcohol fuels and, if not, then whether or not slightly different volatility specifications should be allowed (see Section 2.4.2).

Though the regulation of gasoline quality is a provincial obligation, not all the provinces have formal specifications for gasoline or similar type fuels. Ontario, Nova Scotia and Prince Edward Island require that all gasoline sold within their province meet CGSB Standards. Quebec and Alberta have individual but similar standards.

Oxygenates, blended with gasoline, exhibit different characteristics than they do as pure substances. The CGSB Standards proposal specifies the requirements for a number of these characteristics which affect gasolines and gasoline blends. Three specific standards of concern to gasoline producers are: octane rating, volatility, and oxygen content.

2.4.1 Octane Requirements

An "octane rating" is a measurement of the ignition characteristics of gasolines. The most frequently used measurement to determine octane levels is called the "antiknock index" or "road octane measure." The antiknock index is defined as the average of the Research (R) and Motor (M) octane number for fuel, (i.e., (R+M)/2). The research octane number (RON) measures a fuel's rating under low-speed driving conditions. The motor octane number (MON) measures a fuel's characteristics under high-speed, high-load conditions. Since the MON test conditions are more severe, it is normally the most critical indicator of gasoline quality.[24]

The octane blending values for alcohols are very dependent on the chemical composition of the hydrocarbons into which they are blended as well as vehicle operating conditions. Oxygenates generally have a high research octane number and a lower motor octane number. This would suggest that for some gasolines under high engine loads, the addition of ethanol and methanol might not improve the octane rating at all. Refiners aspiring to achieve specific octane ratings in their fuels must take all these factors into account.[25]

Gasoline produced with an inadequate octane level will result in engine knock or audibly, a "ping." In internal combustion engines, fuel and air are drawn into the combustion cylinders where they are compressed and then ignited by a spark. A "knock" or "pinging" occurs if some of the fuel/air mixture auto-ignites before the ignition spark. The result is excessive pressure from the vibration of the gas in the cylinder, thus creating the pinging sound. Engine knock is a function of fuel characteristics, engine design and driving conditions and is offensive because fuel economy is lost, engine performance is unsatisfactory and damage to the engines head gaskets, valves and piston heads may occur if the condition is not corrected.

In the past, tetraethyl lead has been a cheap and therefore preferred ingredient used to boost the octane levels in fuels. However, as of January 1, 1987, the allowable level of lead was reduced from 0.77 to 0.29 grams per litre. By the end of 1990, Environment Canada plans to have completely eliminated the use of lead in gasoline. These reductions will mean that Canadian refiners will either be requiring other additives or more severe refining of petroleum fuels to supplement octane levels. Alcohols, as well as MTBE, have higher octane values than typical gasolines. The actual blending octanes can vary as much as ± 8 octane numbers, depending upon the oxygenate, as well as the base gasoline stock used.[26] The blending value of oxygenates will be more significant in base fuels with lower octane numbers as well as decreasing aromatic and olefin hydrocarbon content; therefore, alcohol blending values would be higher for "regular" gasolines than for "premium" gasolines (see Tables 2.5 and 2.6).

TABLE 2.5

SEASONAL AND GEOGRAPHICAL SCHEDULE OF MINIMUM ANTIKNOCK INDICES FOR REGULAR UNLEADED OXYGENATED GASOLINE

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Coastal B.C. and Maritimes	86.5	86.5	87.0	87.0	87.0	87.0	86.5	86.5	87.0	87.0	87.0	87.0
Interior B.C., Alberta and Yukon	83.5	83.5	83.5	84.0	84.0	84.0	83.5	83.5	83.5	83.5	83.5	83.5
Saskatchewan	84.0	84.0	84.5	84.5	84.5	84.5	84.0	84.5	84.5	84.5	84.5	84.0
Manitoba, N.W.T. and N.W. Ontario	85.0	85.5	85.5	86.0	86.0	86.0	85.5	86.0	86.0	86.0	86.0	85.5
Ontario (except N.W. Ont.), Quebec and Labrador	86.5	86.5	86.5	87.0	87.0	86.5	86.5	86.5	86.5	87.0	86.5	86.5

SOURCE: Canadian General Standards Board, Draft, May 26,1988.

TABLE 2.6

SEASONAL AND GEOGRAPHICAL SCHEDULE OF MINIMUM ANTIKNOCK INDICES FOR PREMIUM UNLEADED OXYGENATED GASOLINE

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Costal B.C. and Maritimes	90.0	90.0	90.0	90.0	90.0	90.0	89.5	89.5	90.0	90.0	90.0	90.0
Interior B.C., Alberta and Yukon	87.5	87.5	87.5	88.0	88.0	88.0	87.5	88.0	88.0	88.0	88.0	87.0
Saskatchewan	88.0	88.0	88.0	88.5	88.5	88.0	88.0	88.0	88.5	88.5	88.5	88.0
Manitoba, N.W.T. and N.W. Ontario	88.5	89.0	89.0	89.5	89.5	89.0	89.0	89.0	89.5	89.5	89.0	89.0
Ontario (except N.W. Ont.), Quebec and Labrador	89.5	89.5	90.0	90.0	90.0	89.5	89.5	89.5	86.5	87.0	90.0	89.5

SOURCE: Canadian General Standards Board, Draft, May 26, 1988.

2.4.2 Volatility

As noted earlier, one topic creating conflict in designing the CGSB standards is volatility. Volatility measures the rate at which a fuel evaporates, or changes from liquid to a vapour, at a specified temperature and pressure. Volatility specifications are required to ensure smooth acceleration and proper starting and warming of automobile engines in cold weather conditions and at varying altitudes. Fuels which do not reach minimum vapour pressure specifications may have trouble starting at low temperatures. Excessive vapour pressure, however, can result in "vapour lock," which in turn causes the automobile to stall. Refiners, therefore, must and do adjust the volatility of their gasoline to meet engine requirements at different seasons of the year.

Since fuel must be vapourized in order to burn properly in an internal combustion engine, the seasonal and geographical distribution of the Standard volatility classes is determined by the "ambient" temperature in that region. This "ambient" temperature factor has a major effect on the fuel volatility requirements because alcohol-gasoline blends will evaporate more readily than unblended gasolines at higher ambient temperatures; whereas at lower temperatures, the volatility of gasoline can decrease if alcohol is added (see Table 2.7).

There are two methods of measurement used by the CGSB to determine the volatility of gasolines. The Reid Vapour Pressure (RVP) measures fuel evaporation at 100 ^{o}F (37.8 ^{o}C) and is a good determinant of the fuel's "front-end" volatility, which is significant in regards to startability, vapour lock and evaporative emissions. The second method, the American Society for Testing and Materials (ASTM) D86 distillation curve, measures the relative volatility of all the fuel constituents from the initial boiling point to the end point.[27] In other words, the CGSB and ASTM distillation specifications reveal the boiling point at which a percentage of the fuel evaporates.

It is the distillation specifications, as well as the RVP specifications, which control the volatility of gasolines. The vapour pressure of a fuel is important because of its effect on both the vehicle's driveability and the amount of evaporative emissions released into the atmosphere. Higher evaporative emissions from alcohol gasoline blends may result in an environmental problem if these fuels are allowed higher vapour pressures than other gasolines.[28] Adding an oxygenate into gasoline tends to result in reducing the front-end distillation temperatures below those of the base gasoline, even though alcohols by themselves are not particularly volatile. However, it is a non-linear relationship which exists between blending vapour pressure of alcohol oxygenates and the concentration of alcohol in gasolines. This is

TABLE 2.7

VOLATILITY CLASS CHARACTERISTICS FOR UNLEADED OXYGENATED GASOLINE

Gasoline Volatility Class	Reid Vapour Pressure (kPa) ASTM D 323		Distillation Temperature Percent Evaporated (^{o}C) ASTM D 86				
			10%		50%		90%
	Min.	Max.	Min.	Max.	Min.	Max.	Max.
Summer	--	79	35	65	70[a]	120	190
Intermediate 1	--	86	--	60	70[a]	117	190
Intermediate 2	--	97	--	55	70	113	185
Winter	69	107	--	50	70[ab]	110	185

SOURCE: Canadian General Standards Board, May 26, 1988.

[a] Gasoline with 50% points below 75 ^{o}C may need additives to avoid carburetor icing in susceptible vehicles.
[b] Gasoline with 50% points greater than 65 ^{o}C but less than 70 ^{o}C may be provided if the RVP is below 97 kPa.

illustrated by the fact that the first increment of alcohol to gasoline sharply increases the vapour pressure of the blend, but beyond alcohol additions of 3 percent the effect on the gasoline blend vapour pressure becomes negligible.[29] The lighter alcohols, such as methanol and ethanol, when blended with gasoline, result in a disproportionately high increase in the vapour pressure of the fuel at low temperatures whereas MTBE, as an ether, and the heavier alcohols do not seem to have this effect.[30]

The higher fuel volatility which results when either methanol or ethanol is the blending agent, as well as alcohol's affinity for water resulting in decreased freezing problems, combine to improve vehicle driveability in wintertime (if added to a gasoline not already at maximum RVP) but could lead to vapour lock in warmer summer conditions. In order for refiners who produce oxygenated gasolines with lighter alcohols to have their products meet CGSB volatility specifications, they must "tailor" the gasoline to control the vapour pressures. This can be accomplished easily by changing the percentage of butane in the fuel because butane has a high RVP. However, backing out butane which is an inexpensive, readily-available high octane component can result in a significant cost to the refiner. Figure A.1 illustrates the effects which volatility has on engine performance.

The proposed CGSB Standards for oxygenated gasolines would ensure equivalent volatility specifications for both oxygenated fuels and for equivalent grades of gasoline, even though it has been argued that the emphasis on volatility at low temperatures may not be the best measure of gasoline performance and therefore, may not be either appropriate or justified for oxygenated gasolines. Some alcohol producers argue that alcohol/gasoline blends, with higher vapour pressures than other gasoline blends, perform better under certain driving conditions. On the other hand, many of the large integrated oil refiners suggest that to function as a marketable fuel commodity, oxygenated fuels should be interchangeable with regular gasolines and perform to the same standards in automobile engines.

2.4.3 Oxygen Content

Automobile engines take in a certain amount of oxygen from the air in order for combustion to occur. However, too much oxygen results in poor combustion. Tests performed in the United States on engines designed to run on gasoline have determined that up to 3.7 percent oxygen by weight can be included in a fuel without affecting engine performance. The amount of oxygenates being added to a fuel must be limited as oxygenated gasolines are effectively partially combusted hydrocarbons. Therefore, more oxygen is available to complete the combustion process than would otherwise be the case for straight gasoline.

The CGSB standards for oxygenated fuels have set 3.7 percent as the allowed upper limit for oxygen content. To maintain this requirement in oxygenated gasolines, two criteria have been established:

(i) Methanol content cannot exceed 5 percent by volume, and

(ii) Ethanol content cannot exceed 10 percent by volume.[31]

2.5 Gasoline Extenders or Octane Enhancers

Octane enhancers are substances that can be added to fuel to raise the octane number and therefore, act as a substitute for tetraethyl lead. Gasoline extenders are those oxygenates which can themselves have value as a fuel but are most commonly used as blending additives and in greater volume than octane enhancers. A particular oxygenate can, therefore, be considered an octane enhancer or a gasoline extender depending on how it is used. Oxygenates which can be utilized include methanol, ethanol, MTBE, and TBA, although this study will not explore the use of the latter.

It is worthwhile noting that the value of oxygenates as a fuel in the marketplace is dependent on whether it is considered a gasoline extender or an octane enhancer. As a gasoline extender, gasoline marketers surveyed today would not purchase alcohol unless it could be acquired at a substantial discount to gasoline. The size of discount would be determined by the cost of adjusting the gasoline to maintain volatility standards, perceived consumer response to the final cost, as well as the capital cost involved with integrating the alcohol into the scheme of the distribution and retail system. It has been suggested that alcohol blends, when considered solely as gasoline extenders, would require a one cent per litre reduction in the rack price. If the alcohol portion were required to contribute 100 percent of this reduction, then the market value of the alcohol component would, in fact, be very low.[32]

On the other hand, if refiners turn to using alcohols as octane enhancers as lead phasedown occurs, there may be sufficient demand to warrant the capital outlay required for production facilities, in which case the market value of alcohol fuels would become much greater.

Footnotes

[1] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, Cat. No. M92-19/1986E (Ottawa: Ministry of Supply and Services, 1986), p. 8.

[2] St. Lawrence Starch Limited, Phase I: Pre-feasibility Study for a Comprehensive Alcohols Study for the Province of Alberta, prepared for Alberta Agricultural Processing Development Branch, Alberta Agricultural Marketing Services Division, November 1986, p. 82.

[3] Environment Canada, Federal Government Advances Deadline for Elimination of Leaded Gasoline by Two Years, News Release PR-HQ-088-54 (Ottawa: September 13, 1988), p. 2.

[4] Eugene Ecklund, Status of Commercialization of Alternative Fuels For Highway Vehicles, Paper presented at the Energy Technology Conference (XIV) (Washington, D.C.: April 14-16, 1987), p. 1231.

[5] Department of Energy, Mines and Resources Canada, "Transportation Energy Moving Forward, Project Mile: Testing Methanol in Large Engines." Cat. No. M22-1--/1986E (Ottawa: Supply and Services Canada, 1986).

[6] Communications with Don O'Connor, Manager Alcohol Fuel Division, Mohawk Oil Co. Ltd., September 15, 1988

[7] Project MILE (Methanol In Large Engines) is sponsored by the Transportation Energy Division of Energy, Mines and Resources Canada. It was initiated to examine the technical, economic and social aspects of utilizing methanol as a fuel for urban and intercity buses as well as medium- and heavy-duty trucks.

[8] United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One: Context and Analytical Framework (Washington, D.C.: U.S. Government Printing Office, January 1988), p. 13.

[9] Ibid., p. B-1.

[10] Ibid., p. B-2, B-3.

[11] Ibid., p. B-1.

[12] Ibid., p. B-2.

[13] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa: Supply and Services Canada, 1986), p. 10.

[14] Communications with E. Eugene Ecklund, Manager, Engine Technology Programs, Office of Transportation Systems, Department of Energy, CE-151, Washington, D.C., September 7, 1988.

[15] United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One: Context and Analytical Framework (Washington, D.C.: January 1988), p. B-4.

[16] Ibid., p. B-5.

[17] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa: Supply and Services Canada, 1986), p. 10.

[18] United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One: Context and Analytical Framework (Washington, D.C.: January 1988), p. B-2.

[19] Ibid., p. D-6.

[20] United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report Two: The International Experience (Washington, D.C.: Office of Policy, Planning and Analysis, August 1988), pp. 1-4.

[21] United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One: Context and Analytical Framework (Washington, D.C.: January 1988), p. D-6.

[22] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa: Supply and Services Canada, 1986), p. 11.

[23] United States Department of Energy, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One: Context and Analytical Framework (Washington, D.C.: January 1988), p. D-8.

[24] Organization For Economic Co-operation and Development, Environmental Effects of Automotive Transport: The OECD Compass Project (Paris: OECD Publications Service 1986), p. 45.

[25] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa: Supply and Services Canada, 1986), p. 20.

[26] Energy, Mines and Resources Canada, Optimized Linear Program Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries, Study prepared by Hycarb Engineering Ltd., TE-86-5 (Ottawa: March 1986), p. V-1.

[27] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa: Supply and Services Canada, 1986), p. 18.

[28] Energy, Mines and Resources Canada, Alcohol Additives, A New Opportunity in Transportation Fuels, (Ottawa: Supply and Services Canada, 1986), p. 11.

[29] Energy, Mines and Resources Canada, Optimized Linear Program Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries, prepared by Hycarb Engineering Ltd., TE-86-5 (Ottawa: March 1986), p. V-2.

[30] Ibid., pp. V-1, V-2.

[31] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa: Supply and Services Canada, 1986), p.17.

[32] St. Lawrence Starch Limited, Phase I: Pre-feasibility Study for a Comprehensive Alcohols Study for the Province of Alberta, prepared for Alberta Agricultural Processing Development Branch, Alberta Agricultural Marketing Services Division, November 1986, p. 77.

Chapter 3

ETHANOL

3.1 Introduction

Ethanol produced from biomass is a renewable energy source which offers immediate prospects for providing a premium liquid fuel from domestic resources as a partial substitute for conventional petroleum supplies. As an oxygenate with a high octane rating, it becomes a candidate for use as an octane enhancer in gasoline as tetraethyl lead is phased out of our fuels. However, whether biomass-ethanol production will be socially, economically and environmentally justifiable is heavily dependent on a number of criteria, a few of which are:

- petroleum prices;
- the degree to which environmental concerns promote the use of oxygenated fuels to reduce the carbon monoxide and carbon dioxide pollution levels;
- the state of the agricultural industry; specifically,
    - grain prices, which determine the feedstock price for ethanol production,
    - production levels affected by climatic changes and consumer food demand,
    - the demand for protein and animal feeds which determines the value of by-product credits attributed to the price of ethanol
- whether ethanol is accepted as an octane enhancer and not only a gasoline extender; and
- the pace of ethanol fuel technology advancement and to what extent cost-effective production is developed.

3.2 Ethanol: Technical Assessment

3.2.1 Composition and Characteristics

Although ethanol can be produced from ethylene, the demand for ethylene in the petrochemical industry, as well as a perceived need to support our grain producers by providing diverse markets for their crops, suggests that ethanol for transportation fuel use is more likely to be produced by fermentation.

The basis of alcoholic fermentation to produce ethanol is:

Carbohydrate + Water $\xrightarrow{\text{yeast}}$ ethanol + by-products;

$C_6H_{10}O_5 + H_2O \longrightarrow 2C_2H_5OH + 2CO_2$ + yeast + by-products

Table A.1 highlights the physical characteristics of ethanol.

Ethanol's physical and chemical characteristics allow for its multiple uses as a potable alcoholic beverage, a solvent or raw material in the chemical industry, an intermediate chemical in the making of pharmaceuticals, as well as a source of fuel.

Although ethanol can be both stored and used in similar ways to gasoline, substitute materials would be required for some of the metals and elastomers used in current fuel systems which would otherwise degrade in the presence of ethanol. Neat ethanol, with its high flashpoint and broad flammability limits, requires the addition of gasoline components to prevent the formation of flammable compositions in the vapour space of vehicle fuel tanks.[1] Ethanol's energy density would suggest that fuel tanks for this neat alcohol would have to be one and a half times the size required for gasoline, resulting in a 50 percent penalty in fuel weight. An alternative to this would be increased fuelling frequency.[2]

3.2.2 Production Technology

Ethanol can be produced from ethylene, a derivative of the oil refining process, catalytic hydration of ethane, or fermentation of sugars.

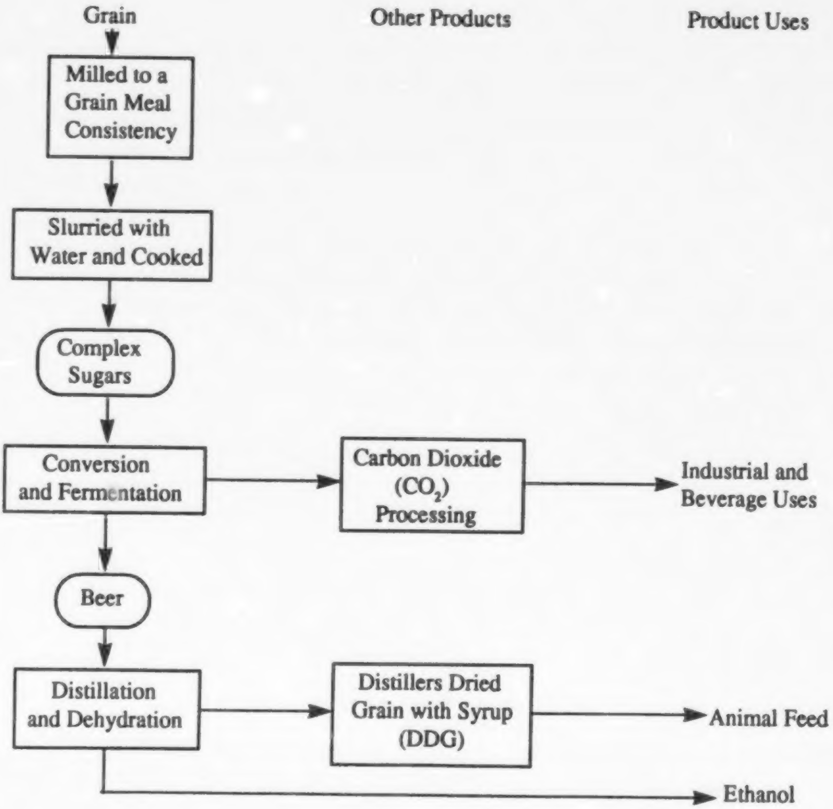
Ethanol fermentation processes consist of three major stages:

- the formation of a solution of fermentable sugars;
- the subsequent fermentation of this solution to a substrate called "beer", which contains dilute ethyl alcohol or ethanol in water; and
- the recovery of the ethanol from beer through distillation.

Additional process stages can be included to upgrade the beer and allow for the production of valuable by-products such as protein-rich animal feed. The market value of the by-products may determine which processing steps may be required for the different feedstocks in order to recover food products such as oil, feed and meal (see Figure 3.1 and 3.2). In fact, a number of proposed plants in Canada are being designed in such a manner that ethanol is the by-product and the solid organic feed is the primary refined product.

Figure 3.1

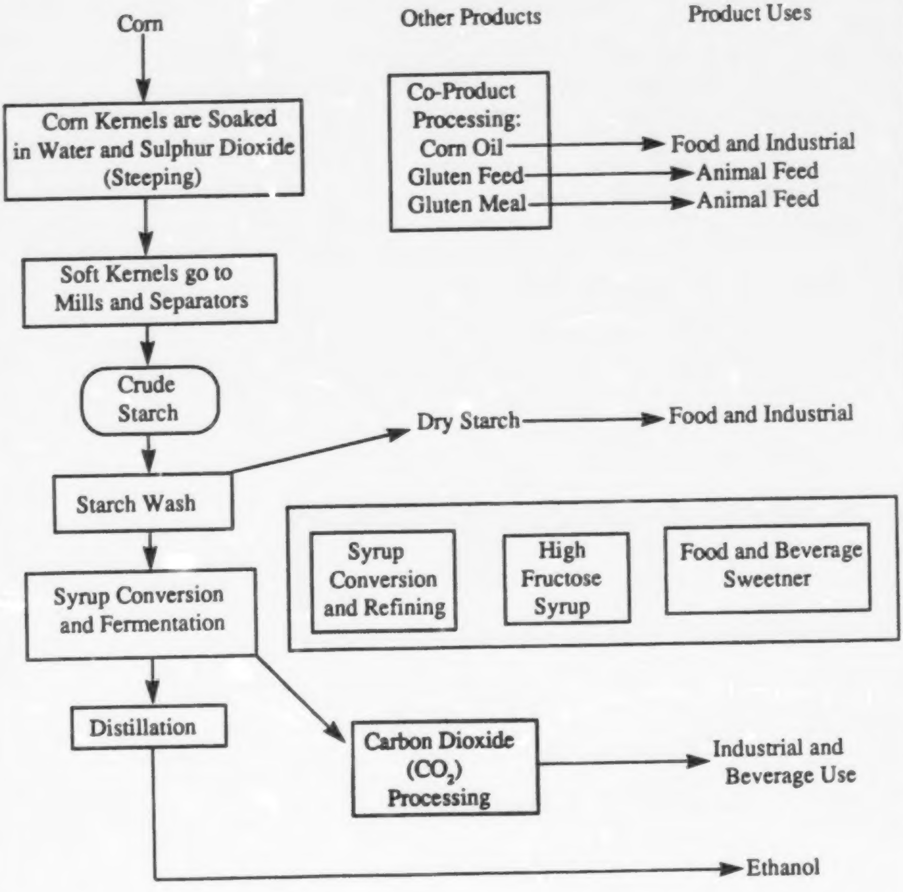
Dry-Mill Processing


Grain
Other Products
Product Uses
Milled to a Grain Meal Consistency
Slurried with Water and Cooked
Complex Sugars
Conversion and Fermentation
Carbon Dioxide (CO_2) Processing
Industrial and Beverage Uses
Beer
Distillation and Dehydration
Distillers Dried Grain with Syrup (DDG)
Animal Feed
Ethanol

SOURCE: U.S. Department of Agriculture, Ethanol, Economic and Policy Tradeoffs.

Figure 3.2

Wet-Mill Processing


Corn
Other Products
Product Uses
Corn Kernels are Soaked in Water and Sulphur Dioxide (Steeping)
Co-Product Processing:
Corn Oil
Gluten Feed
Gluten Meal
Food and Industrial
Animal Feed
Animal Feed
Soft Kernels go to Mills and Separators
Crude Starch
Dry Starch
Food and Industrial
Starch Wash
Syrup Conversion and Refining
High Fructose Syrup
Food and Beverage Sweetner
Syrup Conversion and Fermentation
Distillation
Carbon Dioxide (CO_2) Processing
Industrial and Beverage Use
Ethanol

SOURCE: U.S. Department of Agriculture, Ethanol, Economic and Policy Tradeoffs.

It is the first stage in the design of a production facility which reflects the differences in the biochemical composition of the feedstocks. Obviously, sugar crops would require less complex processing than starch or cellulose-containing raw materials. Starch and cellulose, polymeric molecules built up from single fermentable sugars, must be reconverted to simple sugars before fermentation can occur. Though starch hydrolysis can be accomplished using biocatalysts and enzymes, cellulose hydrolysis using enzymes has still not been commercialized. However, cellulose hydrolysis using mineral acids has been used in parts of the world for the production of ethanol from wood and is now being studied to determine if this process could be developed to meet modern yield and economic requirements (see Figure 3.3).

The fermentation and ethanol recovery stages are similar for all feedstocks, but requirements for additional production stages to yield specific by-products are feedstock and site-specific as well as market-oriented. Currently, producing fuel ethanol from biomass relies on one of two grain processing technologies, dry or wet grain milling. In addition to ethanol, a dry-milling plant yields a protein animal feed known as distilled dried grain (DDG). Carbon dioxide, a by-product of both dry and wet milling, could also be collected for use in food processing, dry ice production or enhanced oil recovery. The ethanol, the DDG or distilled dried grains with solubles (DDGS), and the CO_2 produced account for approximately one-third of the initial weight of the grain. Wet milling yields products such as germ, fiber and gluten and starch components that can be used to produce either ethanol or high fructose corn syrup.

3.2.3 Uses as a Petroleum Substitute

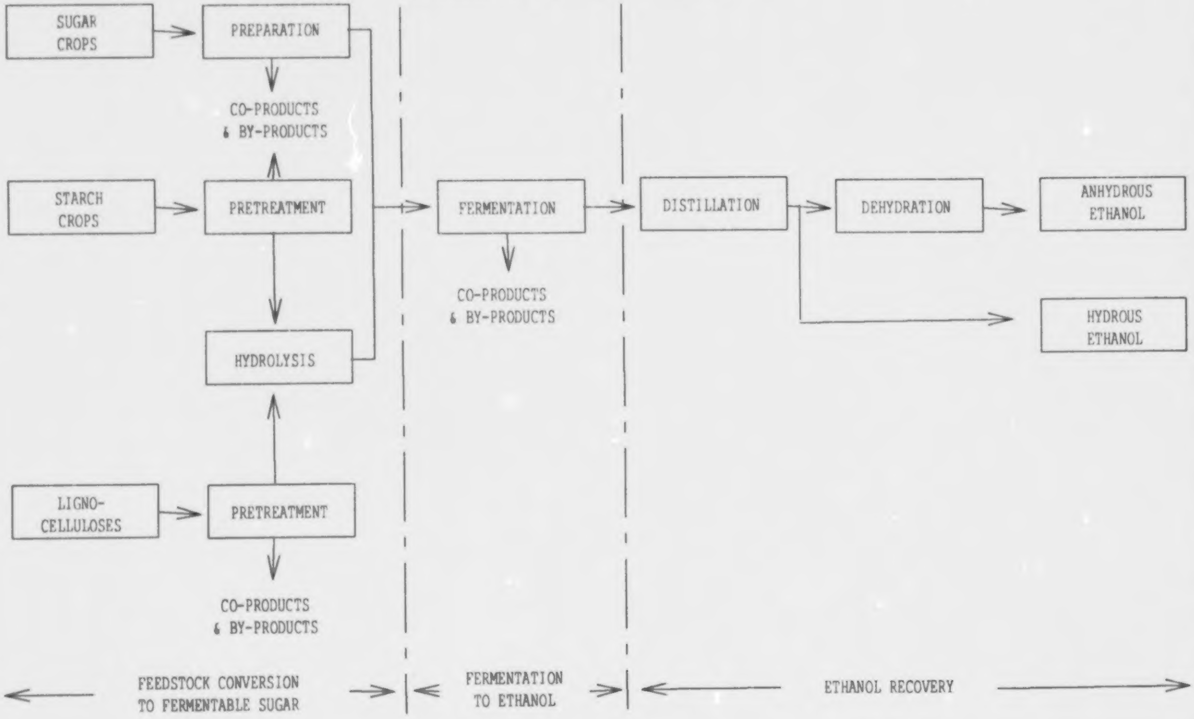
Ethanol produced from biomass has three major applications; as a boiler fuel, a chemical product or feedstock, and a diesel and gasoline substitute.[3]

In relation to fuel oil, ethanol's energy value as a boiler fuel is about 66 percent by weight and 57 percent by volume. As boiler combustion efficiency is essentially 100 percent with overall thermal efficiency in the range of 75-85 percent, ethanol's use as a boiler fuel is unlikely to prove economic in the near future.[4]

Other than in Brazil, where ethanol is used mainly in the fuel industry, chemical applications are still the largest market for ethanol in the world. As a solvent, ethanol from fermentation can be used in the production of pharmaceuticals, toiletries, cosmetics and detergents. Ethanol is also technically a raw material for many chemical products as it can be converted

Figure 3.3

Principal Conversion Steps in Production of Ethanol from Biomass


SUGAR CROPS
PREPARATION
CO-PRODUCTS & BY-PRODUCTS
STARCH CROPS
PRETREATMENT
HYDROLYSIS
LIGNO-CELLULOSES
PRETREATMENT
CO-PRODUCTS & BY-PRODUCTS
FERMENTATION
CO-PRODUCTS & BY-PRODUCTS
DISTILLATION
DEHYDRATION
ANHYDROUS ETHANOL
HYDROUS ETHANOL
FEEDSTOCK CONVERSION TO FERMENTABLE SUGAR
FERMENTATION TO ETHANOL
ETHANOL RECOVERY

SOURCE: International Energy Agency, Alcohols and alcohol blends as motor fuels, Vol. IIA, p. 4:3.

into ethylene by the dehydration process. Since ethylene is the most important intermediate product to the petrochemical industry, large-scale substitution of petroleum products by fermentation ethanol produced from biomass is dependent on ethanol-derived ethylene being competitive with naphtha or ethane-derived ethylene.[5]

Substitution of ethanol for diesel fuel is also being researched at this time, in response to the rapid decline in the quality of diesel fuel in North America and the resulting environmental concerns. A survey undertaken by the U.S. Transportation Research Board between 1972 and 1982 indicated that the average cetane number for diesel fuels had dropped by four points, which suggests an undesirable increase in the aromatic hydrocarbon content. Further, the sulphur content of diesel fuel has increased. Evidence of this was obtained in a survey undertaken by the U.S. Motor Vehicle Manufacturers Association which revealed that between 1980 and 1983, the sulphur content in diesel fuel #1 had risen from 0.19 to 0.31 percent. Though the Brazilian automotive industry, as well as government research institutes, have determined that mixtures of ethanol with various vegetable oils (both with and without gasoline blends) can be used as fuel in diesel cycle engines, it is doubtful at this time whether ethanol could economically replace diesel fuel.[6] It is important to note, however, that as our light and medium crude supplies decrease and their quality begins to deteriorate, a substitute for diesel fuels becomes increasingly important.

It is the use of ethanol as a gasoline blend and/or substitute for a premium petroleum product which has become a focal point of interest to Canadians. As a fuel, ethanol improves the combustion efficiency and octane rating when used in an internal combustion engine. Its physical and chemical properties also change other engine performance characteristics such as starting, carburetion and emissions levels. Ethanol can be used either as "gasohol", where anhydrous (99.8 percent) ethanol is mixed with gasoline up to a 20 percent ratio, or as hydrous alcohol (straight ethanol, 94 percent purity).[7]

The economic value of ethanol as a gasoline substitute varies greatly depending on whether it is used in neat form or in a low-level blend. Current technology available in Canada results in high production costs. Should technological advancement in the breakdown of cellulosics into fermentable sugars allow for the production of neat ethanol at a cost below that of gasoline, and assured markets be determined for the lignin by-product, the circumstances could well change. Further, as the value of gasohol increases as an octane enhancer to replace tetraethyl lead, the viability of low-level blends of ethanol could be greatly enhanced.

3.3 Ethanol: Performance and Compatibility with Current Vehicles and the Fuel Distribution System

3.3.1 Compatibility with Current Vehicles

Ethanol has varying effects on vehicle performance, vehicle emissions and the fuel distribution systems. Straight ethanol, for example, has different combustion properties from straight gasoline. Burning straight ethanol in engines designed to burn gasoline requires major modifications. The cylinder heads and carburetor have to be modified to gain a higher compression ratio in order to efficiently utilize ethanol's higher octane value and combustion properties. Owing to the fact that ethanol degrades some metals and elastomers that are compatible with gasoline, specially-designed materials have to be used for parts of the carburetor, exhaust system and intake manifold. Fuel tanks would also have to be protected using an anti-corrosive paint. In order to prevent the cold weather starting problems associated with ethanol, a small gasoline tank may still be required.

However, up to 20 percent ethanol blend can be used in existing internal combustion automobile engines without modifications.[8] Tests conducted in many countries, including Canada, have demonstrated that cars can obtain about the same fuel economy running on gasohol as when running on regular gasoline. A fleet test was performed over a 2-year period by the Manitoba Department of Energy and Mines, utilizing gasohol with 10 percent ethyl alcohol, produced by Mohawk Oil Co. Ltd. The alcohol was blended with ESSO 2000 unleaded gasoline which was also the fuel used in the control fleet. The conclusions indicated that "no engine modifications or adjustments were needed to convert standard gasoline powered vehicles to gasohol use and indicated no difference in specific fuel consumption for the two fleets."[9]

Most vehicle manufacturers are not against gasohol blends and will honor vehicle warranties if ethanol-blend fuels are used. However, they recommend that vehicle operators switch to straight gasoline if problems are experienced. A number of automobile manufacturers are experimenting with multi-fuel vehicles. An example is Ford's Flexible Fuel Vehicle (FFV) which is fitted with an optical fuel sensor and a modified fuel injection system. The fuel sensor will automatically adjust the vehicle's engine to the blend of ethanol-gasoline fuel mixture in the tank. Ford's FFVs are being developed with financial assistance from the Ontario Ministry of Energy as well as Energy, Mines and Resources Canada (see Table 3.1).[10]

TABLE 3.1

SUMMARY OF VEHICLE MANUFACTURER WARRANTY STATEMENTS FOR 1988 MODEL YEAR ALCOHOL-GASOLINE BLENDS

Company	Gasohol (up to 10% ethanol)	Methanol
Audi Corp.	Allowed if octane requirements of vehicle are met. If problems, switch to gasoline.	Allowed up to 3% with no less than 2% suitable cosolvent. If problems, switch to gasoline.
BMW	Allowed with unleaded gasoline.	Allowed up to 3% with equivalent amount of cosolvent.
Chrysler	May be used. If problems, switch to gasoline.	Avoid all methanol use, could void warranty.
Ford	Allowed if unleaded. If problems, switch to gasoline.	Allowed up to 5% in unleaded gasoline with appropriate cosolvents and corrosion inhibitors. If problems, switch to gasoline.
General Motors	Allowed.	Allowed up to 5% with matching amounts of cosolvent and with corrosion inhibitors.
Honda	Allowed.	Not recommended.
Jaguar	Allowed as long as octane rating is no lower than that recommended for unleaded gasoline.	Allowed up to 3% with cosolvents and corrosion inhibitors.
Hyundai	Allowed in unleaded gasoline. If problems, switch to 100 percent unleaded gasoline.	Avoid all methanol use, could void warranty.
Mazda	Allowed in unleaded gasoline. If problems, discontinue use.	Not recommended.

(Continued on Next Page)

Table 3.1 (Continued)

Company	Gasohol (up to 10% ethanol)	Methanol
Mercedes Benz	Allowed, if all other fuel requirements such as resistance to spark knock, boiling range, vapour pressure, etc. are met.	Allowed up to 3%, ethanol not approved as cosolvent.
Mitsubishi	Allowed. If problems, switch to gasoline.	Not recommended.
Nissan	Allowed. If problems, switch to gasoline.	Allowed up to 5% with cosolvents and corrosion inhibitors. If problems, switch to gasoline.
Peugeot	Allowed.	Allowed up to 3%, plus equivalent amount of cosolvent.
Porsche	Allowed if octane requirements of vehicle are met. If problems, switch to gasoline.	Allowed up to 3% with no less than 2% suitable cosolvent. If problems, switch to gasoline.
Saab	Allowed. Discontinue use if warm starting problems occur.	Allowed up to 5% with matching amounts of cosolvent.
Suzuki	Allowed up to 5%.	Not acceptable.
Toyota	Allowed.	Not recommended.
Volvo	Allowed if blend has an (R+M)/2 rating of 87 or higher. Discontinue use if problems with starting, driveability or fuel economy occur.	Not recommended.

SOURCE: Changes in Gasoline and the Automobile Service Technician, February 1988.

3.3.2 Efficiency

Ethanol exhibits a superior resistance towards "knocking" when compared to many other fuels and even higher values when blended with gasoline. The knock resistance is believed to be improved by the high evaporative cooling effect, relative to that of hydrocarbons, as well as the high autoignition temperatures.[11] As ethanol-blended fuel has a much higher octane rating (110-112) than gasoline (87-89), it shows potential as a substitute for the lead being phased out of our gasoline pool (see Figure 3.4).

A litre of ethanol contains about two-thirds the energy content of a litre of gasoline.[12] This lower energy content results in reduced fuel efficiency. Although this suggests a 3.3 percent increase in fuel consumption with the use of gasohol, a recent report by the U.S. Department of Energy on the performance of alcohol gasoline blends concluded that gasohol-fuelled vehicles averaged 4.7 percent fewer miles per gallon than gasoline-fuelled vehicles.[13] While this contradicts the results of the Manitoba fleet test mentioned earlier, there may be a reasonable explanation. There is evidence which suggests alcohol blends burn more efficiently in internal combustion engines than do gasolines.[14] This would help offset any loss in heating value.

3.3.3 Power and Driveability

The effects on vehicle driveability when using ethanol-blended fuel have been documented in many test programs. This study has only been able to draw conclusions from a limited number of these as many of the tests analyze low-level and high-level alcohol blends, or methanol and ethanol but fail to differentiate clearly between the results of each alcohol blend.

An overview of the results from existing vehicle fleet tests suggests the following:

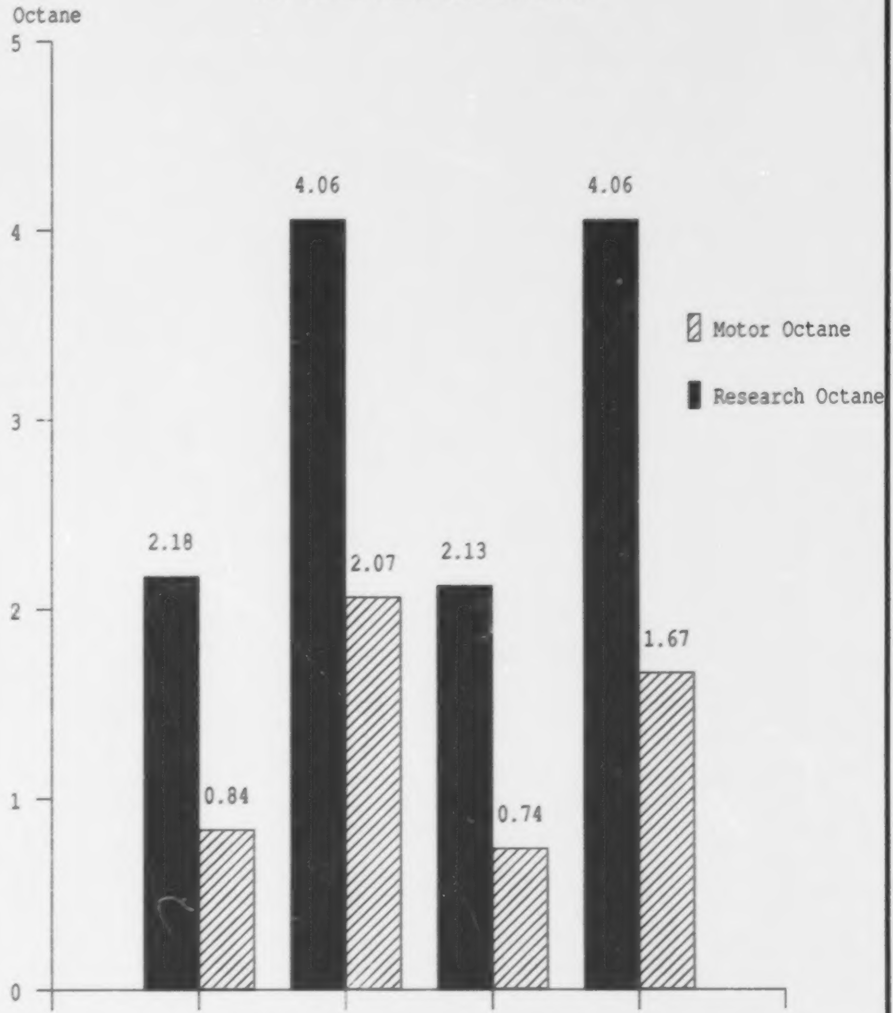
(1) Low-level ethanol blends (in which the oxygen content is limited to between 2 and 2.3 percent by weight) maintain acceptable driveability characteristics.

(2) Warm weather stalling due to high fuel volatility occurs only if the ethanol is not blended with a properly formulated gasoline.

(3) Differences in fuel consumption between low-level ethanol blends and gasoline in general indicated very little disparity, suggesting that gasohol is a relatively more efficient fuel than gasoline considering the ethanol blend has 4 percent less energy per unit mass than gasoline and 3 percent less energy by volume.

Figure 3.4

Octane Number Gains*
from Ethanol and Methanol Blends



* Based on base gasoline having 91.4 Ron, 83.3 Mon.

SOURCE: IEA, Alcohols and alcohol blends as motor fuels, p. 6:14.

(4) Higher level blends of ethanol reveal increasing volumetric consumption in comparison to standard gasoline fuels.

(5) The power output from gasohol is higher than from regular unleaded gasoline.

(6) First-time use of the blend in older vehicles can result in fuel filter clogging. Ethanol is a solvent which causes residues that normally accumulate to break loose and clog the fuel filters. This clogging prevents the fuel from reaching the engine but can usually be solved with one filter change. The newer the vehicle, the less chance there is of this problem occurring.

(7) Phase separation of the blended ethanol fuels may occur if a vehicle is not used for a lengthy period of time. This, in turn, can result in deterioration of plastic fuel lines which may rupture when the car is operated again, creating a definite fire hazard.

(8) With low level ethanol blends, engine wear does not appear to be a concern and conventional lubricating oils can be utilized.

Most of the problems characteristic of low-level ethanol blends can be eliminated or at least reduced by making certain adaptations to existing vehicles, such as substituting incompatible engine parts with compatible items as well as altering the carburetor and ignition system to offset the effects of the lower energy content of the blended fuel.

Flexible fuel vehicles designed to run on gasoline or any ethanol-gasoline fuel mixture up to 85 percent ethanol may provide the solution for the use of ethanol-blend fuels in the near future. St. Lawrence Starch Limited is currently testing two Ford flexible fuel vehicles. The vehicles are giving "very positive performances."[15]

3.3.4 Distribution

3.3.4.1 Transportation

Although ethanol has been successfully "batched" through pipelines, there are definite concerns for the refiner in doing so if the fuel is being shipped through a common carrier pipeline. If a relatively "wet" fuel is shipped through the pipeline prior to sending through a batch of ethanol, for example, the alcohol would simply absorb the water. When the ethanol was later blended with gasoline, phase separation would occur, causing driveability problems for any vehicle fuelled with the blend.

Another problem which can occur in the pipelines is related to the solvent properties of ethanol. When ethanol is shipped through a common carrier pipeline, it may loosen some of the deposits which have precipitated out and line the pipes. This would not only result in contamination of the ethanol blend but may contaminate the next product sent through the pipeline as well.

It should be noted, however, that while sufficient technical experience has been gained to overcome the problems mentioned above, a full solution would involve closer regulation of the pipeline delivery system itself. The pipeline would require thorough cleaning and the water content of all products transported through would have to be strictly regulated. An alternative solution to the problem might be dedicated pipelines for alcohol fuels. Whether the economics would justify such a system is another matter.

Ethanol can be transported effectively by both rail and truck. However, if either transport vehicle has carried a product other than alcohol prior to carrying ethanol, it must be cleaned and purged to prevent contamination of the ethanol product. On the other hand, this is standard industry practice where product switching is involved.

There are also a number of regions in Canada where gasoline is shipped by barge. Again, problems can arise from water penetration/phase separation unless there is consistent cleaning and draining of the tanks, piping and valves. Dedicated vessels, designed to keep their cargos water-free, may be required.

3.3.4.2 Blending and Distributing

Canadian refiners and marketers are concerned about distributing a blended fuel of inferior standards and destroying customer confidence in their product. In order to ensure CGSB Standards are enforced with ethanol-blended fuels, the actual mixing and testing of the fuels should take place at the refinery. There are situations, however, such as common carrier pipeline or marine transport, where intermediate transporting requirements may favour terminal blending. Under these circumstances, tailored gasoline may be prepared at the refinery and the gasoline and ethanol shipped separately to the terminal where they are blended. Increased costs would be incurred by the refiner due to the necessity of making and storing an additional grade or grades of gasoline. Although terminal blending of alcohol fuels can be achieved, there is a concern that quality control may be lost.

Pump blending for fuels containing ethanol may be uneconomical as separate storage tanks would be required for the alcohol. Further, the pumps used to dispense the ethanol blend would require redesigning to accurately blend the derived fuel. As tailored gasoline would be required for blending with the ethanol, separate storage facilities would also be needed for this product as it would be incompatible with the regular product sold at the pumps. This method of blending would not only be expensive but could leave refiners concerned that the quality of the blend would not be maintained and eventually result in unsatisfied customers and unfavourable publicity.

3.4 Ethanol: Environmental Impacts

The use of leaded gasolines in Canada and around the world has distributed lead emission throughout our environment. Lead toxicity has been linked to brain damage in children and hypertension in adults. Ethanol-blended unleaded gasoline could provide one method of facilitating the removal of this deadly octane enhancer from our environment.

3.4.1 Production Impacts

The commercial production of ethanol has been occurring from earliest times. Other than the environmental hazards related to its production from wood, which may require the disposal of acids used in the hydrolysis process, the actual production of ethanol from fruits, vegetables and grains has not resulted in any known environmental hazards of major concern.

3.4.2 Vehicular Emissions

3.4.2.1 Exhaust Emission: HC, CO and NO_x

Exhaust emission studies have elaborated on the effects of ethanol-blended fuels but not on the effects of neat ethanol. An oxygenated fuel blend of gasoline with 10 percent ethanol contributes to enleanment as a result of the oxygen present in the blend itself. Essentially, an oxygenate is a partially combusted hydrocarbon, as part of the process of oxidizing the components has already taken place. Therefore, if a gasoline containing an oxygenated component is fed into the cylinder of a conventional gasoline engine, the amount of oxygen required to complete the combustion process is less than for straight gasoline. As the amount of air taken into the cylinder is effectively the same as for a gasoline engine, in cars intended to run on gasoline, the combustion effect is as though the mixture were lean. In other words, there is more oxygen available to complete the combustion than would be the case for straight gasoline. The effects of this enleanment are reduced exhaust emissions of hydrocarbons (HC) and carbon monoxide (CO), but increased nitrogen oxide (NO_x) emissions.[16]

In a closed-loop vehicle, which has an operating oxygen sensor in control of the engine, increasing the fuel flow until stoichiometry is achieved may compensate for the oxygen present in the fuel. In effect, this should result in a further reduction in exhaust HC and CO emissions. The closed-loop vehicles referred to came into use beginning in 1981 and later.[17]

At higher altitudes, a given volume of air has lower density and less oxygen which generally results in greater HC and CO emissions. Both open-loop vehicles and closed-loop vehicles in their open-modes will operate richer more often than they would at lower altitudes.[18]

3.4.2.2 Evaporative Emissions: HC

Adding ethanol to gasoline will result in a blend with a higher Reid Vapor Pressure (RVP) than the base gasoline. This, in turn, would result in higher hot soak and "diurnal" emissions (see Table 3.2). Hot soak emissions, which arise both from the fuel metering system and the fuel tank, occur immediately after a vehicle is turned off. Carbureted vehicles have greater hot soak emissions than fuel injected vehicles. Diurnal emissions consist of hydrocarbons both evaporated and displaced from the vehicle's fuel tank. The increase in evaporative hydrocarbon emissions, combined with the increase in NO_x emissions, could create ozone attainment problems in some areas during the summer months. However, if effective measures are taken to control the evaporative emissions from ethanol blends through tailoring the gasoline, or if ethanol usage is confined to cold-weather seasons, then the usage of ethanol blends should not affect ambient ozone levels.[19]

Current research suggests that aldehyde emissions increase when ethanol-blended fuels are burned, as both acetaldehyde and formaldehyde are produced. Aldehyde emissions have been found to be as great as 50 percent higher with blends than for straight gasoline. However, the extremely small amounts involved can be efficiently removed by catalysts, thereby reducing the possibility of negative health effects.[20]

3.5 Ethanol: Health and Safety Hazards

3.5.1 Toxicity

The use of neat ethanol as a fuel does not appear to result in risk to human health since concentrations of ethanol in the air of 1000 parts per million (ppm) and greater are required to cause headache, irritation of the eyes and mucous membranes of the upper-respiratory tract, drowsiness and the inability to concentrate.[21] Ethanol sold for use as a fuel must be denatured to avoid being sold as a beverage. It must be noted, however, that although a range of denaturants are available, none to date are deemed totally effective.[22]

TABLE 3.2

EVAPORATIVE VOC TECHNOLOGY-SPECIFIC[a] EFFECTS OF 10 PERCENT ETHANOL BLENDS[b]

(% change from gasoline)

	11.5 RVP Base		9.0 RVP Base	
	Same RVP	RVP + 0.76	Same RVP	RVP + 0.76
100% Share (no commingling)				
Diurnal				
Carb.	-9.66	+80.1	-9.66	+41.13
F.I.	-9.66	+122.2	-9.66	+42.67
H.S.				
Carb.	+14.85	+35.28	+14.85	+25.52
F.I.	-5.70	+20.18	-5.70	+34.01
50% Share (max. commingling)				
Diurnal				
Carb.	+20.97	+96.21	-2.39	+51.72
F.I.	+33.92	+144.90	-3.32	+55.10
H.S.				
Carb.	+18.18	+39.57	+16.20	+28.47
F.I.	+1.57	+24.97	+0.30	+42.36

SOURCE: U.S. Environmental Protection Agency, Guidance on Estimating Motor Emission Reductions From the Use of Alternative Fuels and Fuel Blends, p. 36.

[a] VOC - volatile organic compounds.

[b] These effects include adjustments for lower molecular weight of ethanol and lower number of carbons/gram relative to gasoline vapour. For hot soak (H.S.), adjustments for molecular weight are not used, but for carbureted vehicles an adjustment for distillation (% evaporation @ 160° F) is included.

3.5.2 Flammability

The physical differences between gasoline and ethanol are extremely important when evaluating safety hazards which might occur as a result of traffic accidents, transportation, spillage and storage.

If ethanol is stored in closed containers, the combination of air and ethanol vapour above the liquid's surface is theoretically explosive at temperatures between 10° to 40° C.[23] In the case of gasoline, however, the vapour would be too rich to ignite. Nevertheless, ethanol can be stored in closed tanks without a protective atmosphere such as nitrogen because of its superb conductive properties which reduce the risk of static electricity which can contribute to accidental ignition.

3.5.3 Transportation Hazards

Transporting ethanol in closed tank trailers could present certain risks, which can be reduced by installing flame arresters or vents. Another precautionary measure would be to transport the alcohol with some light hydrocarbons blended into the product which would increase the saturated vapour concentration and lower its flammability limits. If the flashpoint of ethanol and gasoline are considered, spills of ethanol would appear to be less hazardous than those from gasoline. It should be noted that alcohol-resistant foams are available for fire fighting.

As noted earlier, the effects on vegetation caused by ethanol spills remain at least one year which, in most cases, causes a reduction in vegetation after contamination. However, there are no indications that the impact of an ethanol spill on vegetation would be more adverse than the impact of a gasoline spill.[24]

Aquatic ecosystems can also be adversely affected if spillage occurs while transporting ethanol. Crustaceans such as lobsters and crabs may die or exhibit irreversible neuromuscular disruptions at concentrations as low as 1 to 3 percent.[25] These toxic effects increase with the progression along the hydrocarbon chain; therefore, gasoline would pose higher toxicity risks to aquatic life than ethanol which, in turn, would pose higher toxicity risks than methanol.

3.6 Ethanol: Economic Assessment

As a renewable biomass fuel, opportunities exist to produce large quantities of ethanol for transportation fuel applications. As lead is phased out as an octane enhancer from Canadian fuel supplies, there may be a definite need for ethanol to enhance the power of existing gasoline products.

However, these opportunities are confronted with a number of economic costs. Whether the costs will outweigh the benefits is the question confronting Canadians.

There have been several reports published in Canada and a great many in the United States estimating production costs of ethanol from different sites, using various feedstocks and producing diverse volumes of alcohol. Many of the projects for which cost estimates are presented are still in the experimental stage and not yet commercially viable, as, for instance, that of producing ethanol from cellulosics. The point to be made is that each plant is unique in its feedstock characteristics, feedstock costs, operating parameters, plant capacity, by-products and even product quality. There would also be unique financial obligations for each producer such as the debt-equity ratio assumed, the interest rates to be paid as well as the tax status of each company. Taking all these factors into consideration, it was necessary to consult with a number of producers in order to arrive at a fairly demonstrative set of production costs.

3.6.1 Demand

There are many uncertainties surrounding the Canadian energy sector which may affect the level of demand for ethanol production. The level of both crude oil prices and grain feedstock prices will have a tremendous impact on the future price of ethanol and, in turn, the level of demand for this alcohol fuel. As suggested earlier, while crude oil prices are low, the demand for higher priced ethanol as a fuel extender will probably remain low; whereas, if the crude price rises, the demand for the alcohol will likely follow. Also, as grain prices fluctuate, the market price of ethanol will act in a corresponding manner, making ethanol more or less competitive with gasoline. Ethanol will, therefore, be in higher demand when grain prices are low and in lower demand when grain prices are high. The demand for high-protein animal feeds, a by-product of ethanol production from grain, will also affect the level of demand for ethanol, since the price at which ethanol can be economically sold as a fuel is affected by the amount of by-product credit added back to the feedstock.

Price changes are not the only variables which affect the demand for ethanol. For example, lead phasedown will increase the demand for ethanol as an octane enhancer. It is interesting to note, however, that lead phasedown in Canada lags behind that of the United States by 4 years and that during this time, Canada's allowable lead levels will be ten times those allowed in the United States.[26]

Future demand for ethanol in Canada will depend largely on the potential which this oxygenate has, as an alternative to lead, to enhance the octane value of Canadian fuels. It is expected that Canadian refineries were able to meet the CGSB gasoline quality standards for 1987 lead specifications. However, under the 1990 scenario, a number of refineries may fall short of their octane requirements and find ethanol a competitive alternative to other investments such as higher reforming or isomerization.

The selection of ethanol as an octane enhancer depends on other factors, including favourable "characteristic appeal" and its economic comparison with other octane enhancers, such as MTBE. Refineries which develop upgrading facilities, thereby changing the product slate, may subsequently require additional octane enhancers which may include alcohols such as ethanol. Another concern of the refiner is the geographic location of the refinery and the alcohol being produced in relation to the location of the potential market areas. As pipeline capabilities for transporting alcohol/gasoline blends are still uncertain, trucking, rail and/or barge costs have to be considered.

The level of ethanol production costs versus the costs of competing alternative fuel sources also has a significant effect on the level of demand for ethanol. When production costs are significantly higher than those of competing alternative fuel sources, the demand for ethanol will lessen; whereas, when production costs for ethanol are lower than competing fuels, the demand for ethanol will increase. At the moment in Canada, ethanol production costs ($0.35-$0.70 per litre) are too high for ethanol to be sold as a "neat" fuel in competition with gasoline. Recognizing this barrier, the maximum regional demand for ethanol was viewed in this report from the perspective of either ethanol in a 10 percent blend with regular unleaded gasoline, or ethanol in a 5 percent blend with premium unleaded. The penetration rate of these ethanol blends into the Canadian fuel market was estimated at 5 percent per year starting in 1989, with a maximum penetration assumed to be 25 percent.

Improvements in technology which will result in a more cost effective commodity, allowing ethanol to compete more equitably in the fuel market, will also lead to a greater demand.

3.6.2 Reliability of Supply

Canada is rich in its productive farm lands, which are capable of producing the corn, wheat, barley and/or "other" preferred raw materials necessary for ethanol production from biomass. Gasoline refiners, however, still hold reservations about the availability of a continuous and sufficient supply of feedstock to support an ethanol industry which, in turn, must significantly contribute to their octane requirements. The farmers generally maintain that the requisite supplies could be produced. However, the financial consequences faced by the farmer who could not meet his ethanol feedstock commitment would be far from the magnitude of financial loss confronting a large gasoline refiner, as there are only about 29 refineries supplying all of Canada.[27]

Ultimately, the ethanol producer and the farmer would need to work together to assure the refiner of the consistent availability of ethanol, at prices competitive with other alternative octane sources as well as with foreign ethanol supplies. If 10 percent ethanol were to be added to only 25 percent of the entire Canadian unleaded gasoline pool, it would require an ethanol supply of approximately 882 million litres annually from approximately 2.5 million tonnes of grain by 1993, assuming average yields of 350 litres per tonne.

3.6.3 The Value of Ethanol

Canadian ethanol prices must be competitive. They must not only be equated to domestic production costs and market factors but also to the value of the product in the international market. It must be recognized that in a free trade environment, Canadian producers would be vulnerable to U.S. producers restarting some of the currently idle northern tier ethanol plants.

As noted in Section 3.3.2., as a fuel extender ethanol contains two-thirds the energy content of gasoline which ultimately results in reduced fuel efficiency. This suggests that the effective price of ethanol should be around two-thirds of the rack price of unleaded gasoline to be economically competitive on a mileage basis. However, with the octane value of ethanol being 30 percent higher than regular gasoline and 7 percent higher than MTBE, ethanol's value as an octane enhancer would be considerably greater than that of gasoline. If the value of the ethanol blends in the marketplace is to reflect the combined characteristics of a gasoline extender and an octane enhancer, its selling price could go as high as approximately $0.37 per litre.[28] As a neat fuel, the economic viability of ethanol is poor; however, as a gasohol or in an M5E3 or Premium Plus blend, ethanol's value as an octane enhancer may, under certain assumptions, be a viable investment (see Table 3.3).

Another factor that affects the actual value of ethanol as a blended fuel is the volume of gasoline components (crude oil and butane) from the refinery which must be replaced if the same product slate and volatility specifications are to be maintained. As crude oil is more expensive than butane,

TABLE 3.3

PRICING ETHANOL BLENDS BASED ON FUEL VALUE (1988 Cdn. cents/litre)

	M5E3	Gasohol	Premium Plus[a] (+5% ethanol)
As a Gasoline Extender:			
1. Current rack price of unleaded gasoline[b]	23.00	23.00	24.00
2. Marketing Incentive[c]	1.00	1.00	1.00
3. Net Price of blended fuel	22.00	22.00	23.00
4. Price of gasoline portion	21.16	20.70	22.80
5. Price of methanol portion ($0.18/l)	0.90	–	–
6. Required price of ethanol portion	(-2.0)	13.00	4.00
As an Octane Enhancer:			
1. Current rack price of unleaded gasoline	23.00	23.00	24.00
2. Market value over unleaded gasoline[d]	10%	10%	10%
3. Price of blend	25.30	25.30	26.40
4. Price of gasoline portion[e]	23.28	22.77	25.08
5. Price of methanol portion ($0.18/l)	0.90	--	--
6. Required price of ethanol portion[f]	37.47	25.30	26.40

SOURCE: Canadian Energy Research Institute.

[a] See Footnote 29.

[b] Rack prices supplied by Turbo Resources Limited and represent average prices received for unleaded gasoline from various cities across Canada.

[c] The "Pre-feasibility Study For A Comprehensive Alcohols Study for the Province of Alberta," done by St. Lawrence Starch Limited for Alberta Agriculture, suggested that selling ethanol as a gasoline extender in the marketplace may require a marketing incentive of one cent per litre.

[d] According to the United States Department of Energy, in their January 1988 publication, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, engines optimized to use ethanol should be about 10 percent more efficient.

[e] This calculation of the value of the gasoline in the blend assumes that the alcohol addition increases the value of the gasoline.

[f] The required price of the ethanol is obtained by taking:
(3-(4+5)/ethanol portion).

the higher the crude backout from the gasoline pool, the better the economics of the blended fuel. However, the highly volatile nature of ethanol suggests that during the summer months, in order to maintain CGSB volatility standards, the base gasoline would have to be tailored in a manner which would suggest higher butane backouts and lower crude backouts, resulting in a more costly fuel. In 1986, Hycarb Engineering Ltd. completed an analysis for Energy, Mines and Resources Canada, "Optimized Linear Program Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries", in which the refinery value of oxygenates was determined. The study found that "the current specifications affect alcohols adversely, especially those with the highest volatility, such as 10 percent ethanol and 5 percent methanol/3 percent ethanol."[30] Current specifications would require the addition of these oxygenates to backout more butane than crude oil to meet "percent off" requirements, thus adversely affecting the price of the blended fuel.

3.6.3.1 Feedstock Availability and the Distilled Dried Grain (DDG) Market

The financial stability of ethanol production is extremely dependent upon the feedstock costs as well as the value of the resulting by-products.

To assure feedstock availability for an ethanol plant, it is essential to choose a feedstock crop which is in plentiful supply in the region being considered. The Western provinces have a wealth of barley and wheat crops and the Eastern provinces have abundant supplies of corn. All three of these crops have a high starch content and therefore make good feedstock for an ethanol industry. It is important to note that feed grade grains may in themselves provide an opportunity for ethanol producers to attain cheap feedstock while at the same time providing an alternate market for these poorer grade grains.

The feedstock consumed by the plant is processed by either dry or wet milling. The one feed by-product of the dry milling process is distiller's grains; whereas, the wet milling process produces such by-products as oil, germ, gluten feed and gluten meal. Although the value of the by-products from dry milling is lower than those from wet milling, the latter requires a greater initial capital outlay and therefore a large-scale ethanol facility to take advantage of economies of scale. Whichever milling process is used, it is extremely important that the ethanol producer locate the plant in an area with an assured by-product market. As wet milling is more expensive than dry milling, for the purpose of this study it was assumed that the primary process used is the dry milling process.

Without the credit value of the by-products being attributed back to the costs involved in producing ethanol, the current economics of ethanol production become totally nonviable. It was with this understanding that Klein Economic Consulting Ltd. was engaged to determine what value should be assigned to distiller's dried grains (DDGs) in Canada, under the assumption of a penetrated market. Appendix F summarizes its findings. The economic sensitivities that were performed on DDG prices utilized values suggested by this study so that the economics would not be crediting unrealistic value to a commodity which reflects an extremely high value at the moment, but may be worth somewhat less in a fully saturated market.

It should also be noted that further research into the value and uses of these high protein feed by-products may result in the production of human grade protein which would greatly increase the by-product credit.

3.6.3.2 Integration of Site, Feedstock and Feedlot

As noted in Section 3.6.3.1, the current economic viability of an ethanol plant is directly related to reducing the production costs through crediting back to the ethanol costs the value of its by-product. It would therefore seem beneficial to integrate a feedlot with an ethanol plant. Both capital and operating cost savings could thus be maximized.

As both ethanol plants and feedlots require the feed grain to be processed, savings could result from the need for only one processing facility. The distiller's grains, a highly nutritious animal feed which would otherwise involve drying, shipping and storage costs, can be fed directly to the cattle in the feedlot along with the thin stillage or sweetwater produced. It may also be beneficial to integrate with a grain handling facility to assure storage space for excess feedstock in the off-season. Extensive operating cost savings might also be realized from sharing management, labour and technical resources as well as office space, utilities and equipment. If this industry, which is dependent on such diverse markets as the grain, livestock feed and energy sector, is to become economically viable, benefits can definitely be derived from optimizing the returns from its by-products through integration.

3.6.4 An Empirical Assessment of the Ethanol Industry

This section of the report will present an empirical assessment of the economic outlook for an ethanol industry in Canada, based on data gathered from numerous public and confidential studies. To begin with, four plant sizes are analyzed (10, 50, 100 and 200 million litres per year per plant). Promoting an ethanol industry as an agricultural diversification project would require plants around the 10 million litre per year size so the animal feed by-product could be completely utilized in an integrated feedlot. However, to promote the use of ethanol as a fuel on a national basis requires larger, commercial scale facilities of the 50, 100 and 200 million litres per year size.

3.6.4.1 Financial Criteria

The financial criteria used to determine the viability of the project were:

- Rate of return on investment; and
- Payout or payback period.

The rate of return on investment specifically takes into account the time value of money and the cash flows over the life of the facility. It is defined as the discount rate that equates the present value costs (capital and operating) of the project with the present value benefits (revenue from both ethanol and by-products).

The payout period refers to the time period required for the cumulative cash flow to turn from negative to positive; in other words, the time it takes to recover the capital invested.

3.6.4.2 Financial Evaluation

Financial evaluations were performed under a range of assumptions pertinent to an ethanol industry. This enabled the examination of the impact of uncertainty on the economics of the projects.

To investigate the factors determining the financial profile of an ethanol industry, a financial evaluation of four hypothetical grass roots ethanol plants was undertaken. The assumptions underlying the evaluation are provided in Table 3.4. All four plants (10, 50, 100, 200 million litres per year capacity) have a start-up profile of 0 percent, 60 percent, 90 percent and 100 percent and a project life of 10 years. This time period was chosen simply because, as indicated by the actions of U.S. ethanol producers, if after 10 years the project is not viable, the plant will most likely be shut down. Construction of the plants was assumed to take place in 1988.

3.6.4.3 Production Costs

The cost of ethanol production for fuel use in Canada will vary considerably, depending on the site and size of the plant. Large producers will have an inherent advantage in terms of their ability to more effectively

TABLE 3.4

FINANCIAL EVALUATION PROJECT CHARACTERISTICS OF BASE CASES, 1988-1998[a,b,c,d]

(10, 50, 100 and 200 litre/yr. refineries)

	Pessimistic	Mid-Range	Optimistic
Assumptions			
Ethanol yield (litres/tonne)	350	350	350
Ethanol price ($/litre)	0.35	0.40	0.45
DDG price ($/tonne)	170	170	170
Feedstock cost ($/tonne)	110	110	110
Tax rate (%)	44.8	44.8	44.8
Debt/Equity ratio	0/100	0/100	0/100
DCF Return on Investment	15%	15%	15%
Project life (years)	10	10	10
10 mm litres/year			
Operating costs ($000's)[e]	56,457	54,557	51,707
Capital costs ($000's)	15,000	12,000	10,000
50 mm litres/year			
Operating costs ($000's)[e]	268,036	258 536	244 286
Capital costs ($000's)	75,000	55,000	35,000
100 mm litres/year			
Operating costs ($000's)[e]	517,071	498,071	469,571
Capital costs ($000's)	115,000	90,000	65,000
200 mm litres/year			
Operating costs ($000's)[e]	1,015,143	977,143	920,143
Capital costs ($000's)	200,000	160,000	120,000

SOURCE: Canadian Energy Research Institute.

[a] See Footnote 31.

[b] CO_2 assumed not sold, amounts given in constant Canadian dollars, investments assumed to be made on July 1, 1988.

[c] Operating costs include feedstock plus "other" costs, but exclude depreciation.

[d] The variables changing in the base cases are the ethanol price and the capital and operating costs.

[e] Operating and capital cost figures are cumulative over the 10-year life of the plant.

market the fuel as well as realizing production cost savings related to economies of scale. The marketing of fuel ethanol may require both the influence and the financial resources of the large ethanol producers. There are circumstances, however, under which smaller plants can be viable and profitable, a good example of which is Mohawk's ethanol plant in Minnedosa, Manitoba. It is an ideal micro-model, where the plant provides local area farmers with a market for their grain production and, in turn, the local area farmers and residents provide the refinery with a market for both their ethanol fuel and the DDG. However, it should be noted that the economics of this ethanol plant would be more positive than for a grass roots plant as the capital outlay would be far less when acquiring an old distillery than when constructing a new plant.

The production costs for an ethanol plant can be scaled down by locating the plant near:

(i) the feedstock source, which may be:

  - corn or cereal grain,
  - fermentable wastes from a food processing or industrial facility, or
  - pulp, if the technology can be developed to economically break the cellulose down to fermentable sugars;

(ii) a grain elevator for year-round storage and feed access;

(iii) a feedlot where the by-products can be fed directly to the cattle, saving drying, transporting and marketing costs; or

(iv) an oil and gas refinery, where the ethanol can be blended with gasoline.

Much of the controversy surrounding the actual cost of ethanol production relates to its dependence on the variable costs of the feedstock used as well as the by-product prices. As can be seen in Table 3.5, over the the past 12 years corn prices have varied from $81.85 to $160.68 per tonne. Canada feed wheat prices have varied from $87.54 per tonne to $167.86 per tonne, and barley prices have varied from $53.28 per tonne to $124.01 per tonne. As illustrated, grain prices were on the decline for most of those 12 years.

Another pertinent variable which can vary both annually and regionally are the yields per acre from the diverse crops which Canada produces. The ethanol yield also varies by type (see Figure 3.5).

TABLE 3.5

GRAIN PRICES[a]
1977-1988
($Cdn.)

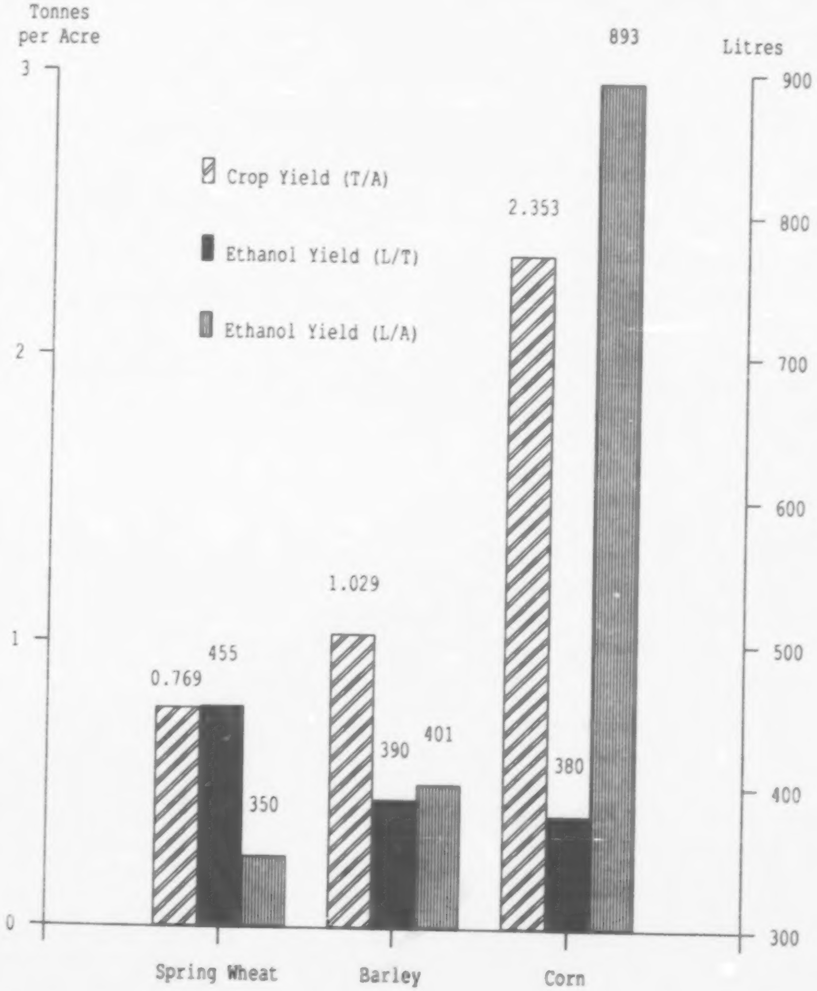
Year	Corn[b] (Ont. & Que. Avg.)	Barley[c] (Alta. feed)	Wheat[d] (Winnipeg)
1977	86.67	79.00	103.80
1978	81.85	67.52	93.18
1979	107.22	73.95	110.18
1980	120.64	110.23	134.70
1981	151.91	124.01	167.86
1982	119.97	103.80	146.17
1983	114.72	91.40	132.30
1984	160.68	114.37	164.46
1985	140.91	120.34	158.68
1986	118.03	88.19	119.18
1987	93.36	61.55	90.26
1988	90.00	53.28[c]	87.54

SOURCES: Ontario Corn Producers Association, Alberta Grain Commission, The Winnipeg Commodity Exchange.

[a] See Footnote 32.
[b] Crop year average prices.
[c] Calendar year average prices.
[d] Year to April.

Figure 3.5

Ethanol and Crop Yields



Note: Crop Yields represent Canadian Average 1977 - 1987.
Source: Canadian Grains Industry, Statistical Handbook 87, Canadian Energy Research Institute.

Unit operating costs, other than unit feedstock costs, vary depending on plant size. The "estimated" unit operating costs net of depreciation, derived from both public and confidential data provided by ethanol producers, suggest that the remaining fixed plus variable operating costs for the four plant sizes should range as follows:[29]

10 million litre/year plant:	$0.23 - $0.28/litre
50 million litre/year plant:	$0.20 - $0.25/litre
100 million litre/year plant:	$0.18 - $0.23/litre
200 million litre/year plant:	$0.17 - $0.22/litre

As indicated, unit operating costs for larger plants tend to be less than those for smaller plants due to the advantages attributed to economies of scale.

3.6.4.4 Base Case Results

Based on the assumptions provided above, as well as in Table 3.4, the current prospects for a viable ethanol industry in Canada (on a stand-alone basis) do not appear to be positive. Even under the optimistic scenarios where ethanol would sell at $0.45 per litre and operating and capital costs are low, the 10 and 50 million litre per year plants fail to pay out, the 100 million litre plant attains a 4 percent rate of return after 10 years of production, and the 200 million litre plant achieves a rate of return of 7 percent after 10 years (see Table 3.6 and Table 3.7). After 20 years, these same cases yield the following results; no rate of return for the 10 million litre optimistic cases; 6 percent for the 50 million litre optimistic case; 10 percent for the 100 million litre optimistic case; and 13 percent for the 200 million litre optimistic case.

The larger plants appear to be more viable than the smaller plants. This exemplifies the benefits of economies of scale experienced by the larger plants which provide a savings of 5 to 6 cents per litre on the operating costs and 5 to 8 cents per litre on the capital investment in comparison with a 10 million litre per year plant.

3.6.4.5 Sensitivities

To investigate the effect of changes on key input variables on the economic returns to an ethanol producer, a number of sensitivity cases were performed on the base cases. In each case, the impact of the changes on the rate of return and payout period was recorded.

TABLE 3.6

FINANCIAL RESULTS OF BASE CASES[a]

	Optimistic
Referring ahead to Table 3.7, the only cases that reached payout over 10 years in the base cases were:	
100 mm litres/year	
Payout year	1996
Rate of return	4
200 mm litres/year	
Payout year	1995
Rate of Return	7

SOURCE: Canadian Energy Research Institute.

[a] As there are no subsidies involved in the base cases and the ethanol price and by-product price received for all the plants is the same, the unit total revenue will be the same for all the base cases.

TABLE 3.7

UNIT REVENUES, 1988-1998[a]
(10, 50, 100, 200 million litres/year plants)

	Pessimistic	Mid-Range	Optimistic
Unit Revenues Achieved			
Unit ethanol price	0.350	0.400	0.450
Unit by-product price	0.155	0.155	0.155
Unit total revenue	0.505	0.555	0.605
Unit Revenues Required to Breakeven			
10 mm litres/year[b]			
Operating costs ($000's)	56,457	54,557	51,707
Capital costs ($000's)	15,000	12,000	10,000
Taxes ($000's)	--	--	750.45
Unit revenue required ($)[c]	0.76	0.71	0.65
50 mm litres/year[d]			
Operating costs ($000's)	268,036	285,536	244,286
Capital costs ($000's)	75,000	55,000	35,000
Taxes ($000's)	--	--	11,382
Unit revenue required ($)[c]	0.73	0.67	0.61
100 mm litres/year[e]			
Operating costs ($000's)	517,071	498,071	469,571
Capital costs ($000's)	115,000	90,000	65,000
Taxes ($000's)	--	826	24,758
Unit revenue required ($)[c]	0.67	0.63	0.59
200 mm litres/year[f]			
Operating costs ($000's)	1,015,143	977,143	920,143
Capital costs ($000's)	200,000	160,000	120,000
Taxes ($000's)	--	5,380	59,004
Unit revenue required ($)[c]	0.64	0.61	0.58

SOURCE: Canadian Energy Research Institute.

[a] The operating costs, capital costs and taxes presented are the consolidated costs over a 10-year life.

[b] 95 mm litres averaged over 10 years.

[c] Unit revenue required to achieve a payout by 1998.

[d] 475 mm litres averaged over 10 years.

[e] 950 mm litres averaged over 10 years.

[f] 1900 mm litres averaged over 10 years.

The Significance of Shifts In Feedstock Prices

Shifts in feedstock prices can definitely enhance or reduce the value of a project. However, shifting the feedstock costs from $110 per tonne to $85 per tonne still did not increase the value of the 10 million litre per year optimistic case to where it pays out after 10 years.

The 50 million litre per year optimistic case improved sufficiently to attain a 10 percent rate of return (from no rate of return) 10 years after the plant commences commercial production. However, lowering the feedstock prices by $25 per tonne was still not enough to bring the mid-range or pessimistic cases on-stream.

The 100 million litre per year plant would experience an increase in rate of return by 11 percentage points in the optimistic case, from 4 percent in 1998 in the base case to 15 percent in 1998 in the $85 per tonne case, plus payout 3 years earlier. Raising the feedstock prices by $30 per tonne completely eliminates the rate of return on the optimistic case.

The 200 million litre per year plant would also attain an increase of 10 percentage points in the optimistic case, from 7 percent in 1998 to 18 percent in the $85 per tonne case, and pay out 2 years earlier. The mid-range case reaches a payout in 1998 with a rate of return of 1 percent. However, a $30 increase in feedstock price relative to the base case wipes out the rate of return in this case also.

As Table 3.8 suggests, a decrease in feedstock prices of $25 per tonne can increase the value of the projects by as much as 11 percent; whereas, raising the price by $30 per tonne results in all the projects remaining non-viable over 10 years. A sensitivity analysis performed on these same cases, extending the project life to 2008, suggests that over a longer period of time lowering the value of the feedstock by $25 per tonne, although beneficial to all the plants, would prove to be most profitable to the smaller 10 million litre per year plant (see Table C.1).

The Value of DDG to an Ethanol Project

Crediting back the revenue from the distilled dried grains by-product to the ethanol project is extremely significant to the economics of an ethanol plant. Table 3.9 is clearly illustrative of this fact. Selling the DDG for $50 per tonne more ($220 per tonne) than the $170 per tonne base case is not enough to bring even the optimistic 10 million litre per year plant on-stream. However, the rate of return on the 50 million litre per year

TABLE 3.8

SENSITIVITY TO FEEDSTOCK COSTS
1988-1998
(10, 50, 100, 200 million litres/yr. plants)

	10		50		100		200	
Case Description	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)
Feed At $85/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	1998	1
Optimistic	-	-	1994	10	1993	15	1993	18
Base Case - Feed At $110/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	1996	4	1995	7
Feed At $140/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	-	-	-	-

SOURCE: Canadian Energy Research Institute.

SENSITIVITY TO DDG PRICES
1988-1998
(10, 50, 100, 200 million litres/yr. plants)

Case Description	10		50		100		200	
	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)
DDG Prices at $280/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	4	1998	1	1996	5
Optimistic	1997	3	1993	14	1993	18	1992	21
DDG Prices at $220/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	2	-	-
Optimistic	-	-	1995	7	1994	11	1993	14
Base Case - DDG Prices at $170/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	1996	4	1995	7
DDG Prices at $130/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	-	-	1998	1

SOURCE: Canadian Energy Research Institute.

optimistic case is increased from no rate of return to 7 percent with payout in 1995. The payout on this plant would be 2 years earlier (in 1993) and receive a 14 percent rate of return if the DDG price was raised further to $280 per tonne.

A $50 per tonne increase in the DDG price (to $220 per tonne) increases the value of the 100 million litre per year optimistic case from 4 percent to 11 percent and advances the payout period by 2 years (1996 to 1994). A further $60 per tonne increase (to $280 per tonne) raises the rate of return on the optimistic case to 18 percent with payout in 1993. The mid-range case also turns positive under this price scenario. Lowering the DDG price $40 (to $130 per tonne) from the base case eliminates any return on the 100 million litre project.

The 200 million litre per year case jumps from a rate of return of 7 percent with payout in 1995 in the optimistic case to 21 percent with payout in 1992 in the $280 per tonne DDG price scenario. Also, at $280 per tonne, the mid-range case comes through in 1996 and attains a rate of return of 5 percent by 1998. The $130 per tonne DDG price scenario decreases the rate of return in 1998 from 7 percent in the base case to 1 percent.

These results underline the importance of maintaining assured prices and markets for this animal feed if an ethanol industry is to achieve and maintain commercial viability. The effects of varying both DDG and feedstock prices to attain specific rates of return on each of the base cases can be determined from Figures C.1 through C.4, respectively.

The Effect of Changes in Ethanol Yield

Increasing the ethanol yield by 50 litres per tonne on all four plant sizes did not allow any of the pessimistic or mid-range cases to become viable. Table 3.10 indicates that increasing the yield from 350 litres per tonne to 400 litres per tonne adds at least 3 percent to the optimistic base case rates of return and brings the payout a year closer. Decreasing the yield 50 litres per tonne to 300 litres per tonne lowers the optimistic case rates of return by at least 4 percent and pushes the payout out another 2 years.

Once again, extending the project life from 1998 to 2008 increases the profitability of these cases anywhere from 2 to 6 percent (see Table C.3).

SENSITIVITY ON ETHANOL YIELD PER TONNE OF FEEDSTOCK
1988-1998
(10, 50, 100, 200 million litres/yr. plants)

	10		50		100		200	
Case Description	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)
Ethanol Yield 400 Litres/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	1997	3	1995	7	1994	10
Base Case - Ethanol Yield 350 Litres/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	1996	4	1995	7
Ethanol Yield 300 Litres/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	-	-	1997	3

SOURCE: Canadian Energy Research Institute.

The Value of Government Subsidies Versus Government Grants To An Ethanol Industry

Section 3.6.6 suggests a number of technological advancements which, in the future, may lead to the financial viability of an ethanol industry in Canada. However, as seen above, current technology does not provide the necessary economics. At today's costs of ethanol production, its usefulness as an "economically" viable fuel source or an "economic" substitute for tetraethyl lead does not appear sound. However, lead phaseout and increasing public pressure to minimize any detrimental effects on the environment from fossil fuel combustion suggests there may well be a role for alcohol fuels in Canada. The need for regional diversification projects may also lend credence to this issue. As illustrated, however, government support would be a necessity to place this fuel on an equal footing, competitively, with other fuel sources. Fuel tax exemptions will not be adequate to support the 10 million litre agricultural diversification projects, let alone that of a large scale commercial project. This suggests that if ethanol is to be produced as a fuel source, government grants and/or subsidies will be required (unless future technological advancements allow for economic viability).

Tables 3.11 through 3.13 illustrate the effect of government capital and/or subsidies on the base cases presented in this report. Figures 3.6a through 3.6d illustrate graphically, for the different size plants, the value of the government subsidy required to offset various levels of capital investment to achieve specific rates of return. In Table 3.14, a government capital grant of 50 percent of the total project capital requirement is compared, in terms of cost to the government, to the level of subsidy that would allow the plant to achieve the same rate of return.

Keeping the benefit to the plant constant, Figures 3.7a through 3.7d suggest that for plants requiring assured rates of return of less than approximately 8 percent, the cost to the government would be less if investment in the project was maintained through subsidies. However, if the required rate of return is higher, the capital cost to the government by 1998 would be less with investing the necessary capital to maintain these rates of return, as opposed to applying subsidies to the project.

Of these two promotional incentives, capital investment or "upfront" money may be the only method capable of promoting interested developers to participate in an ethanol industry. The risk of subsidies being reduced or even removed reduces and inhibits the confidence level among the interested parties.

TABLE 3.11

CAPITAL ASSISTANCE[a]

1998 Rate of Return (%)	Capital[a] ($ millions)	NPV Gov't. Cost Without Taxes[a] ($ millions)	NPV Gov't. Cost With Taxes[a] ($ millions)
10 mm Litres Mid-range[b]			
-	--	--	--
-	--	--	--
-	--	--	--
50 mm Litres Mid-range			
0	50.88	47.45	47.09
5	51.87	48.37	47.95
10	52.58	49.03	48.55
15	53.06	49.48	48.94
100 mm Litres Mid-range			
0	66.93	62.41	60.41
5	72.52	67.63	65.30
10	76.44	71.28	68.57
15	79.13	73.79	70.79
200 mm Litres Mid-range			
0	99.05	92.36	87.06
5	113.83	106.15	100.00
10	124.17	115.79	108.64
15	131.29	122.43	114.51

SOURCE: Canadian Energy Research Institute.

[a] No subsidy assistance.

[b] Since net cash flows for year 1989 onward are negative, government capital assistance in the absence of subsidies will not allow for payout.

TABLE 3.12

SUBSIDY ASSISTANCE[a]

1998 Rate of Return (%)	Subsidy[a] (¢/l)	NPV Gov't. Cost Without Taxes[a] ($ millions)	NPV Gov't. Cost With Taxes[a] ($ millions)
10 mm Litres Mid-range			
0	18.1	7.76	6.71
5	23.3	9.98	8.38
10	29.4	12.60	10.21
15	36.3	15.56	12.24
50 mm Litres Mid-range			
0	13.8	29.57	24.75
5	18.5	39.64	32.31
10	24.1	51.64	40.69
15	30.4	65.13	49.98
100 mm Litres Mid-range			
0	9.1	39.00	31.10
5	12.9	55.28	43.33
10	17.6	75.42	57.40
15	22.7	97.27	72.42
200 mm Litres Mid-range			
0	6.70	57.42	43.47
5	10.20	87.42	66.00
10	14.30	122.56	90.51
15	18.80	161.12	117.04

SOURCE: Canadian Energy Research Institute.

[a] No government capital assistance.

TABLE 3.13

SUBSIDY ASSISTANCE WITH 50 PERCENT GOVERNMENT CAPITAL

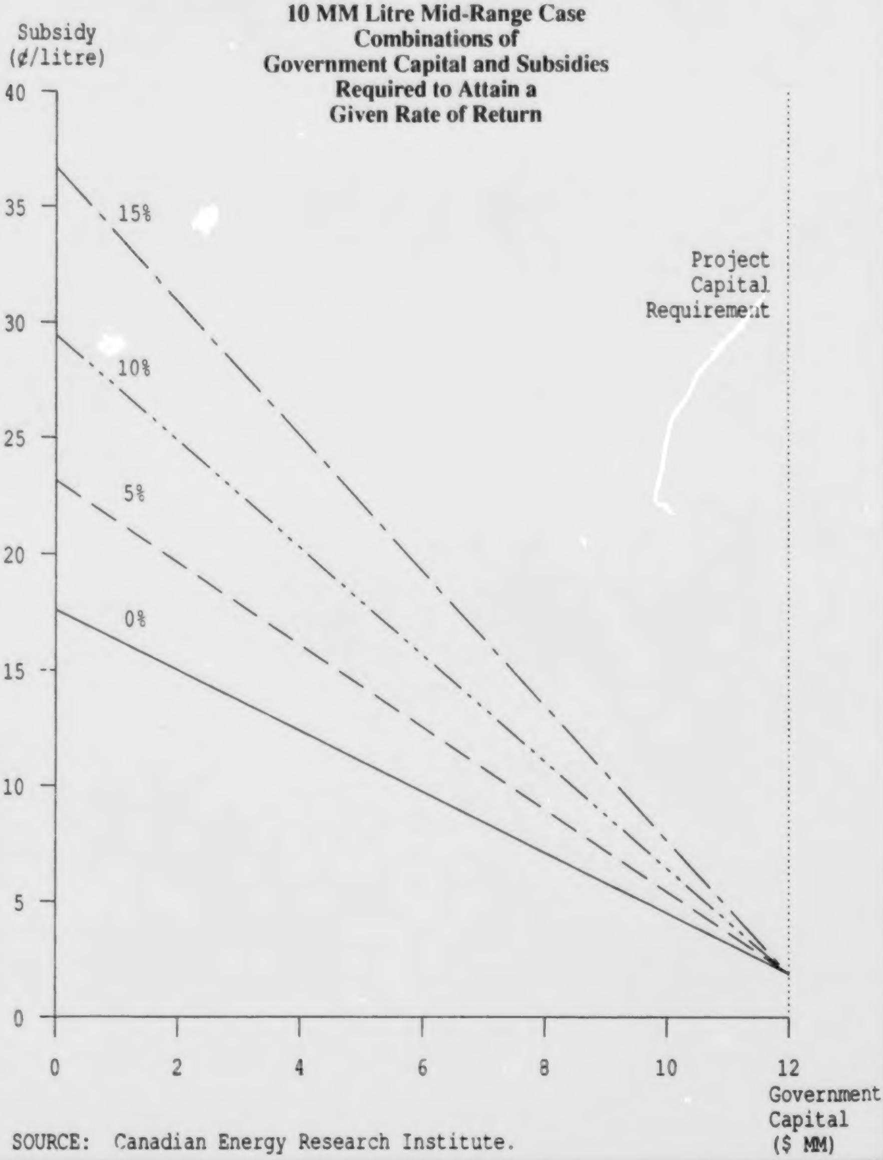
1998 Rate of Return (%)	Subsidy (¢/l)	NPV Gov't. Cost Without Taxes ($ millions)	NPV Gov't. Cost With Taxes ($ millions)
10 mm Litres Mid-range[a]			
0	10.00	9.88	9.36
5	12.60	10.99	10.19
10	15.70	12.32	11.12
15	19.10	13.78	12.12
50 mm Litres Mid-range[b]			
0	6.30	39.14	36.75
5	8.70	44.28	40.62
10	11.50	50.28	44.81
15	14.70	57.14	49.52
100 mm Litres Mid-range[c]			
0	3.00	54.82	50.86
5	4.90	62.96	56.57
10	7.20	72.82	63.86
15	9.80	83.96	72.00
200 mm Litres Mid-range[d]			
0	1.30	85.74	78.75
5	3.00	100.31	89.70
10	5.10	118.31	102.27
15	7.40	138.02	115.81

SOURCE: Canadian Energy Research Institute.

[a] $6 mm government capital.
[b] $27.5 mm government capital.
[c] $45 mm government capital.
[d] $80 mm government capital.

Figure 3.6[a]

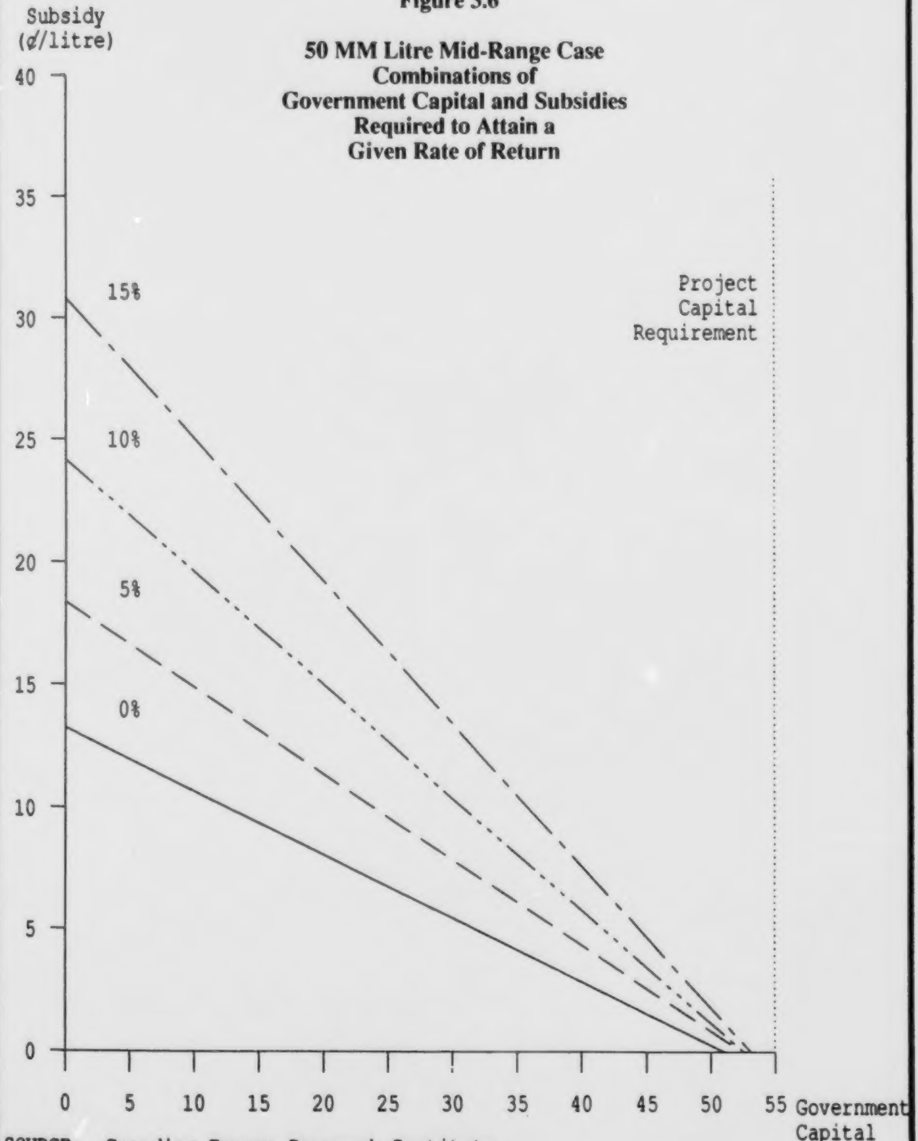
10 MM Litre Mid-Range Case Combinations of Government Capital and Subsidies Required to Attain a Given Rate of Return



SOURCE: Canadian Energy Research Institute.

Figure 3.6[b]

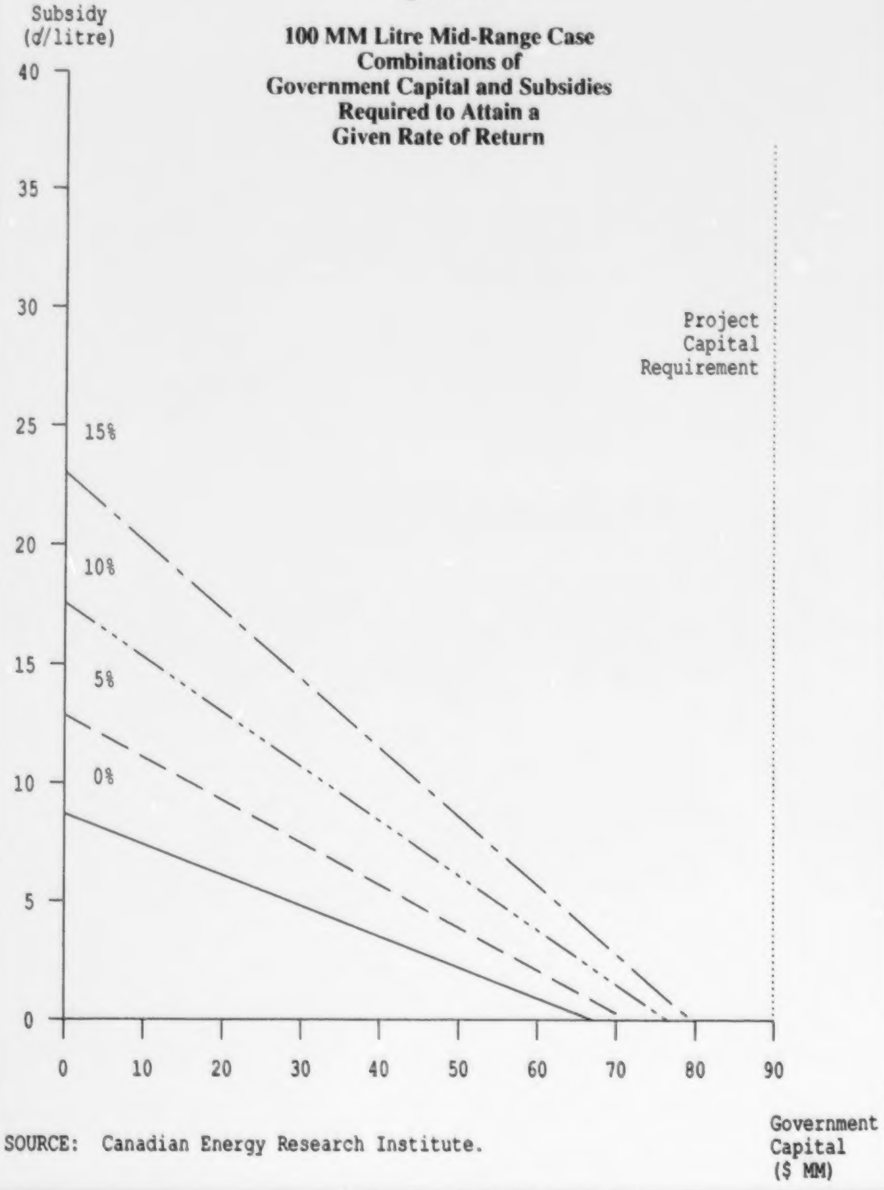
50 MM Litre Mid-Range Case
Combinations of
Government Capital and Subsidies
Required to Attain a
Given Rate of Return



SOURCE: Canadian Energy Research Institute.

Figure 3.6^{c}

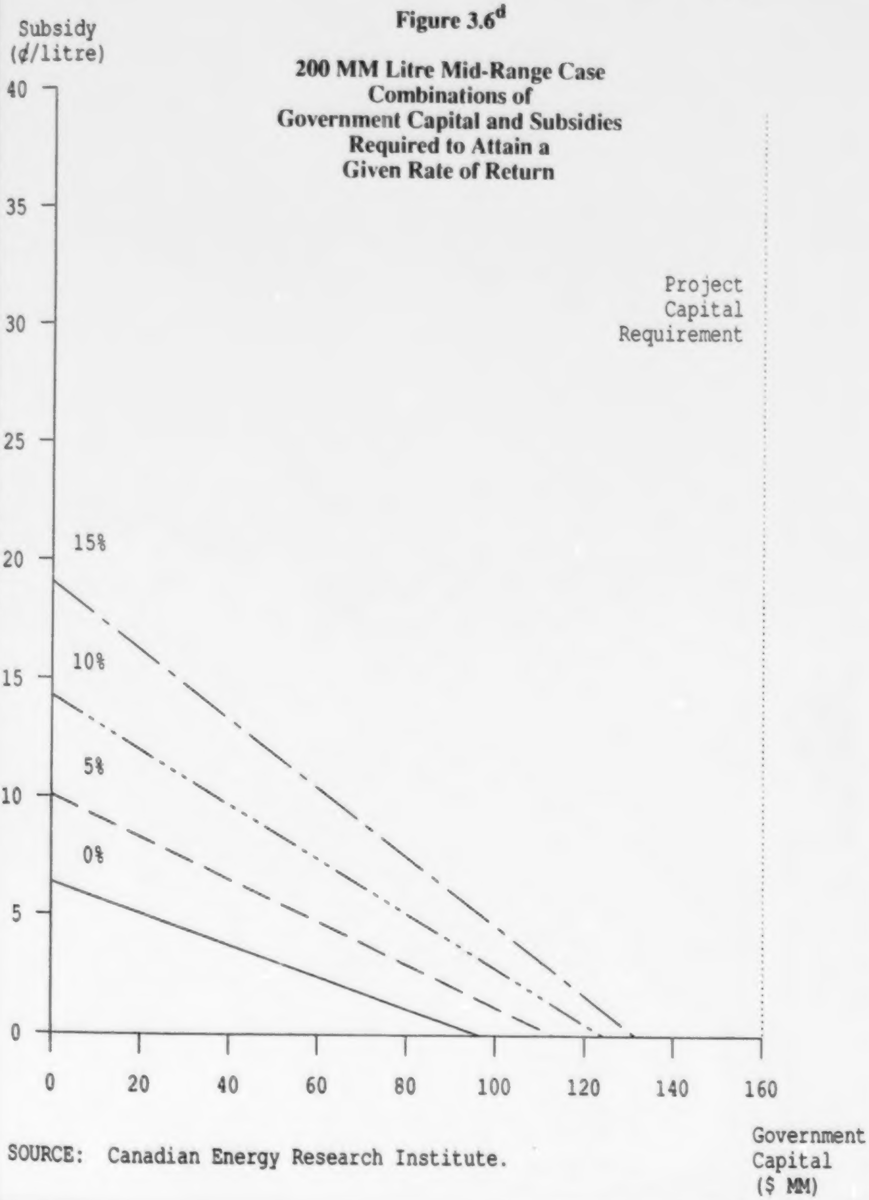
100 MM Litre Mid-Range Case
Combinations of
Government Capital and Subsidies
Required to Attain a
Given Rate of Return



SOURCE: Canadian Energy Research Institute.

Figure 3.6[d]

200 MM Litre Mid-Range Case
Combinations of
Government Capital and Subsidies
Required to Attain a
Given Rate of Return



SOURCE: Canadian Energy Research Institute.

TABLE 3.14

GOVERNMENT SUBSIDY EQUIVALENT TO GOVERNMENT INVESTING 50% OF TOTAL CAPITAL

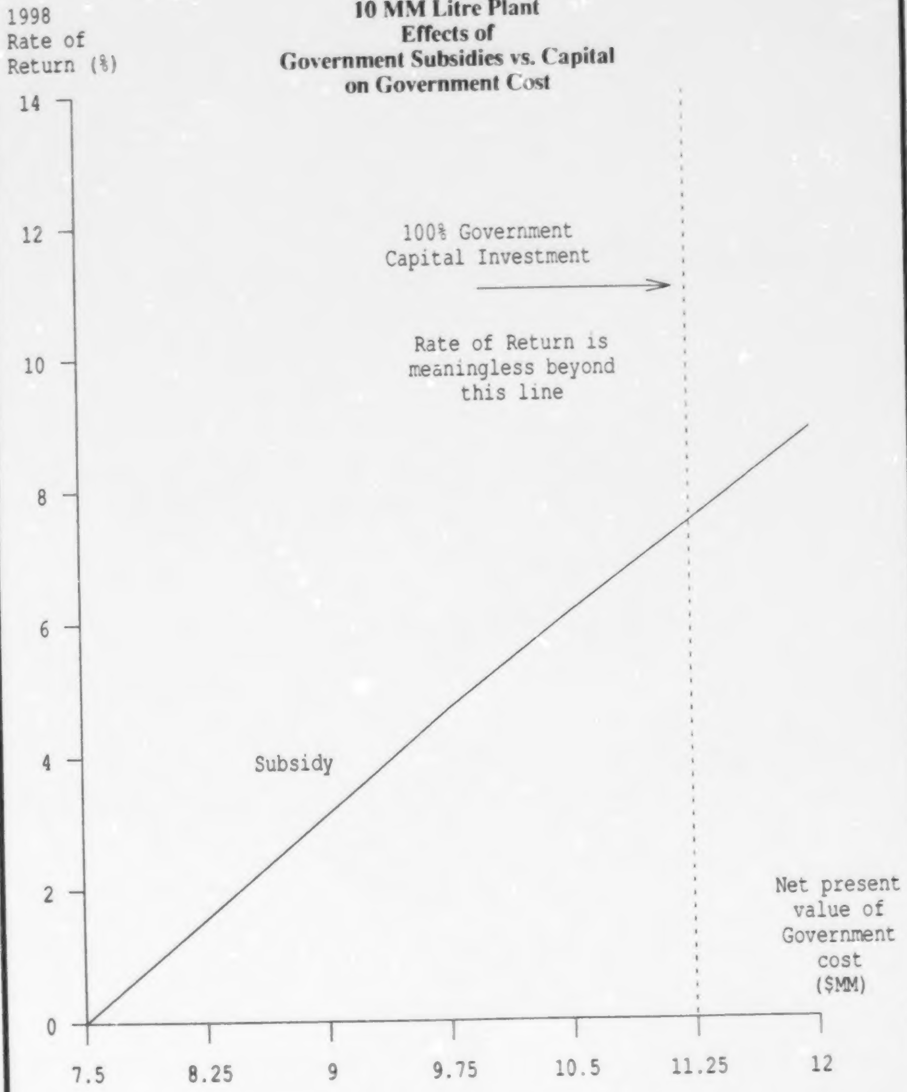
	1998 Rate of Return With 50% Gov't. Cap. (%)	Subsidy Necessary To Achieve Same Rate of Return (¢/l)	NPV Cost of Gov't. Cap.		NPV Cost of Gov't. Subsidy	
			Without Tax ($ millions)	With Tax ($ millions)	Without Tax ($ millions)	With Tax ($ millions)
10 mm Litres						
Optimistic[a]	--	6.11	4.66	4.30	2.62	1.88
Mid-Range[b]	--	--	--	--	--	--
Pessimistic[b]	--	--	--	--	--	--
50 mm Litres						
Optimistic	12.76%	9.11	16.32	12.11	19.52	11.11
Mid-Range[b]	--	--	--	--	--	--
Pessimistic[b]	--	--	--	--	--	--
100 mm Litres						
Optimistic	19.02%	11.11	30.31	18.41	47.61	23.83
Mid-Range[b]	--	--	--	--	--	--
Pessimistic[b]	--	--	--	--	--	--
200 mm Litres						
Optimistic	22.90%	12.11	55.95	27.35	103.87	44.60
Mid-Range[c]	--	4.11	74.60	70.32	35.22	26.67
Pessimistic[b]	--	--	--	--	--	--

SOURCE: Canadian Energy Research Institute.

[a] Project reaches payout in 1999.
[b] Project never reaches payout.
[c] Project reaches payout in 2002.

Figure 3.7[a]

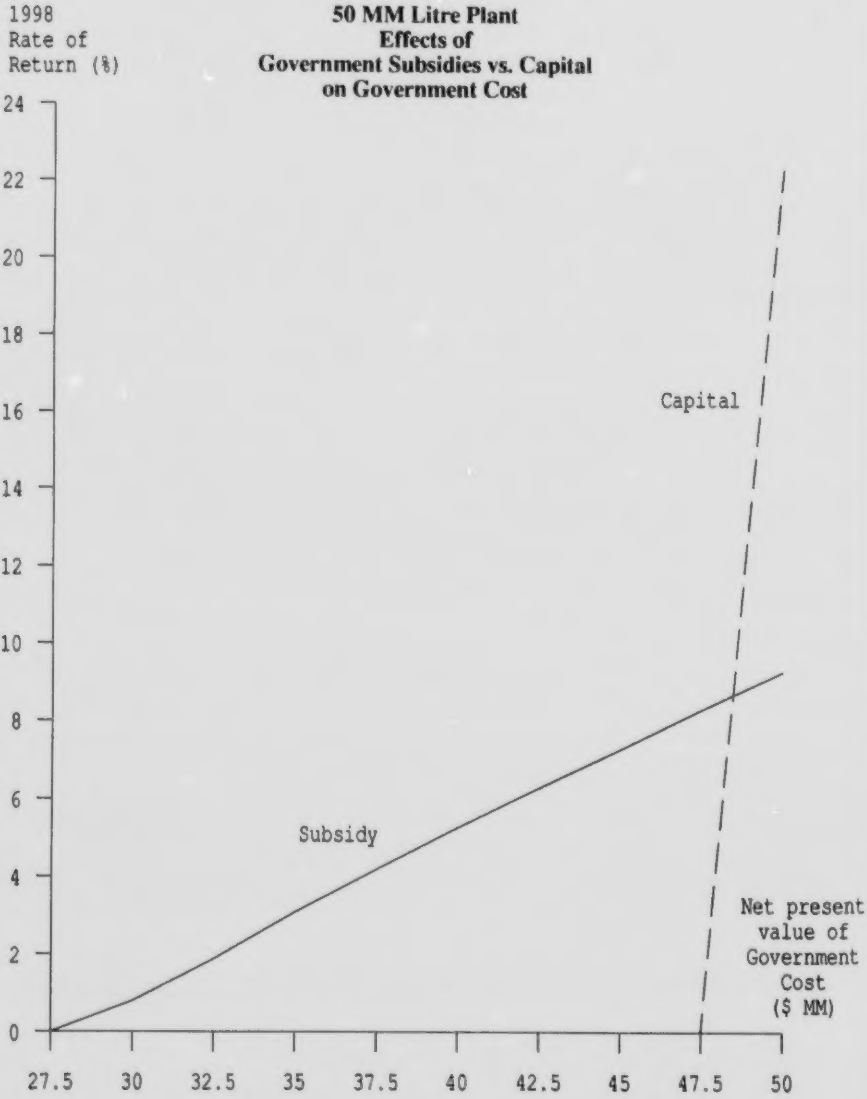
10 MM Litre Plant
Effects of
Government Subsidies vs. Capital
on Government Cost



SOURCE: Canadian Energy Research Institute.

Figure 3.7[b]

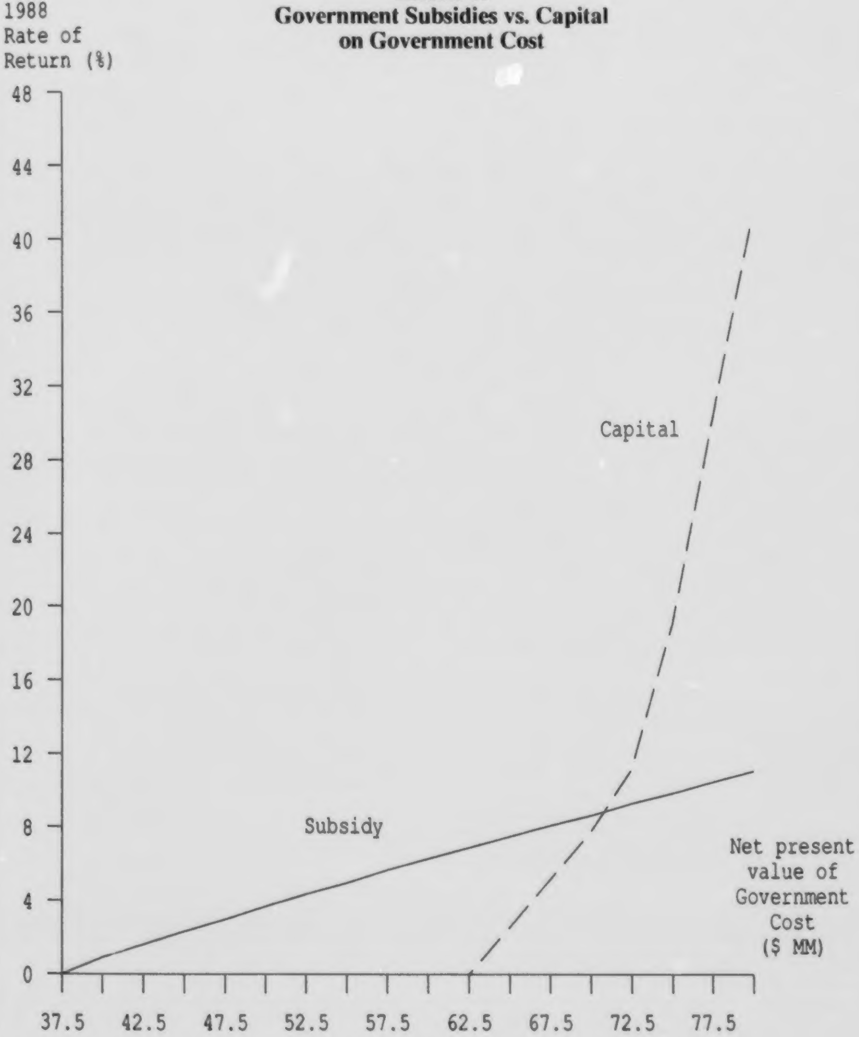
50 MM Litre Plant
Effects of
Government Subsidies vs. Capital
on Government Cost



SOURCE: Canadian Energy Research Institute.

Figure 3.7[c]

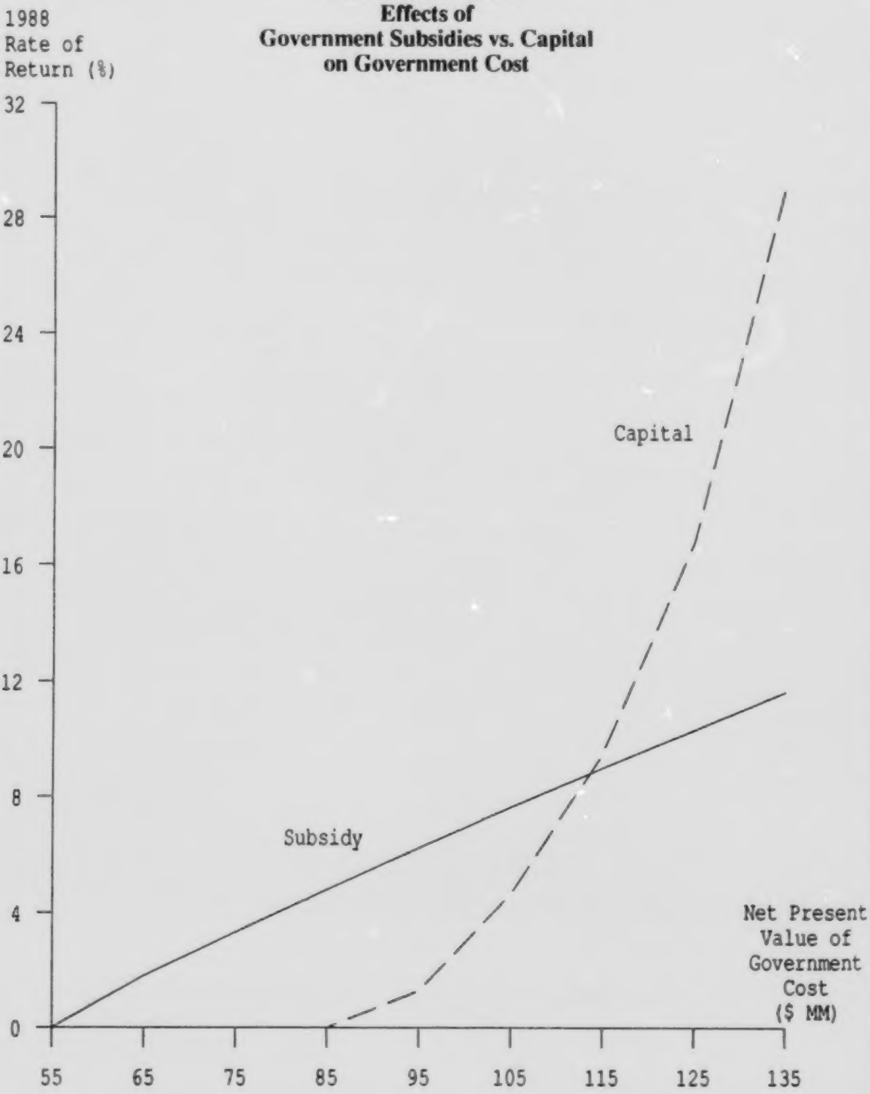
100 MM Litre Plant Effects of Government Subsidies vs. Capital on Government Cost



SOURCE: Canadian Energy Research Institute.

Figure 3.7[d]

200 MM Litre Plant Effects of Government Subsidies vs. Capital on Government Cost



SOURCE: Canadian Energy Research Institute.

SENSITIVITY - NO TAXES UNTIL PAYOUT
1988-1998
(10, 50, 100, 200 million litres/yr. plants)

Case Description	10		50		100		200	
	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)	Payout Year	1998 Rate of Return (%)
No Taxes Until Payout								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	1997	2	1994	6	1994	9
Base Case								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	1996	4	1995	7

SOURCE: Canadian Energy Research Institute.

It should be noted that the cases presented which project the government investing a percentage of the capital required do not allow the capital invested by the government to be depreciated for tax purposes. This point may be a question to negotiate if government discussions of this nature arise. Cases where government capital was and was not allowed to be depreciated were run, and since the projects being investigated paid such low levels of tax under the scenarios examined, the effects on the rates of return for the various projects were very small.

Eliminating tax liability prior to project payout raised the rates of return on the 50, 100 and 200 million litre per year plants by 2 percent, but had no effect on the 10 million litre per year plant as it never accrues a tax liability (see Tables 3.15 and 3.16).

TABLE 3.16

THE EFFECT OF SUBSIDIES ON THE 10 MILLION LITRE CASES
(1998 rate of return)

	No Subsidy	25¢/l	40¢/l
Optimistic	--	17%	26%
Mid-Range	--	6%	17%
Pessimistic	--	--[a]	8%

SOURCE: Canadian Energy Research Institute.

[a] Pays out in 2001.

3.6.5 Provincial Incentives

At the moment, there is no federal incentive program for ethanol fuels. However, a number of provinces do provide support for oxygenated fuels:

- British Columbia has proposed an effective rebate of $0.20 per litre on the provincial road tax for the ethanol portion of a gasohol blend, if an ethanol project begins operating in B.C.
- Alberta offers a $0.05 per litre tax rebate on the oxygenate portion of motor fuels.
- Saskatchewan provides a $0.04 per litre grant for a 10 percent ethanol blend; however, if the distributor is marketing a blend of less than 10 percent ethanol, a grant is paid in proportion to the amount of ethanol in the blend (i.e., if the

blend contains 3 percent ethanol, the incentive is 1.2 cents per litre on the blend).

The incentive will be guaranteed to the distributor for each contract the distributor has with a producer. The guarantee period is 4 years and begins when the distributor first takes delivery of the ethanol from a producer. A participant in the Ethanol Production and Marketing Incentive Program also relinquishes participation in any additional provincial government support program such as the Venture Capital Program or SEDCO.

- Manitoba offers a $0.25 per litre rebate on ethanol containing not more than 1 percent water, derived from biomass, manufactured in Canada, denatured and in not less than 10 percent concentrations with gasoline.
- Ontario offers a full tax rebate on its $0.093 per litre road tax for the alcohol portion of a blended fuel.

3.6.6 Technological Advancement

Ethanol can be a viable alternative as an octane substitute for lead if technological advancement provides for a dramatic drop in its prices. Since feedstock costs contribute approximately half the value of the operating cost attributed to ethanol production, research and development into cheaper feedstock sources could greatly enhance the economics of an ethanol industry.

Present ethanol feedstocks are mainly wheat and barley in the west and corn in eastern Canada. It must be recognized, however, that the Maritimes have large-scale potato production which would make excellent feedstock for the industry, and British Columbia has vast supplies of wood pulp. Also, Sunroot Energy Limited of Mississauga, Ontario has done a great deal of research over this past year quantifying the use of Jerusalem artichokes in place of corn; a single planting produces 3 to 5 years of crop if only the tops of the artichokes are used.

The use of cellulose material to produce ethanol has still not been commercially proven in Canada. The development of an enzyme which will allow cellulosics to be fermented and then distilled would bring about dramatic advancements for the ethanol industry. Techtrol Ltd. of St. Laurent, Quebec has been experimenting with cellulosics, striving to develop an enzyme which would allow the molecular structure of the cellulose to be transformed into glucose. If the enzyme were developed, it has been suggested that ethanol could be produced at costs well below the rack price of gasoline.

Perhaps the Canadian ethanol industry will also require the development of a grain with high yield per acre and high starch content, which could be easily stored, would be less perishable than existing feedstocks and possess good co-product value. Such a crop could be dedicated as feedstock for an alcohol fuel industry. The price of the feedstock could then be set at levels which would benefit both the farmer and the ethanol producer.

Another area that should be thoroughly researched is the value of the protein by-product produced when dry milling corn or fermenting cereal grains. It has been suggested that this high protein source could be upgraded to become a human grade protein source.

There are other technological advancements that could have a major impact on the desirability of an ethanol industry in Canada. However, both time and money must be invested in the short term in order to determine if Canadians would continue to benefit into the long term.

3.7 Ethanol: Conclusions

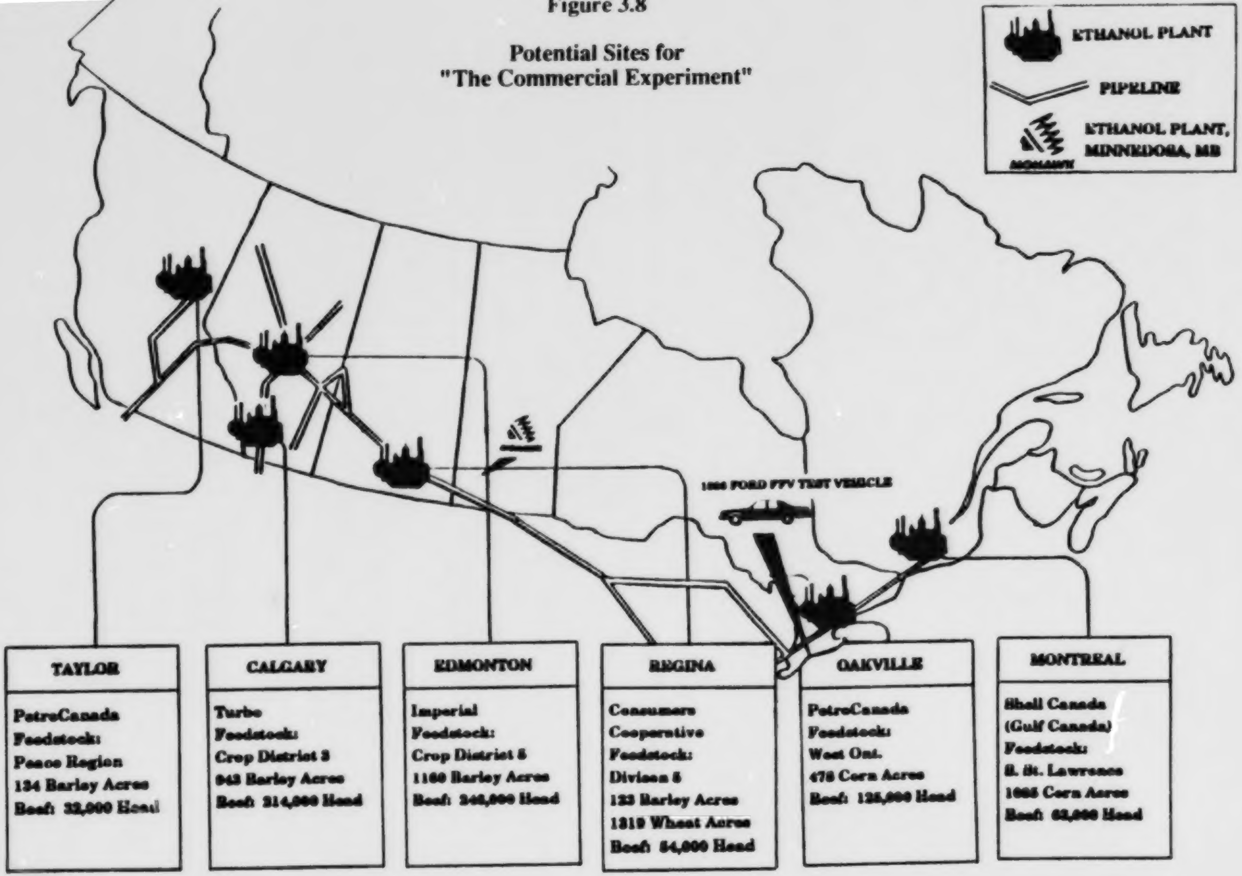
In the long term, the marketplace will determine the ultimate value of ethanol to Canada. However, in the short-term, capital investments ought to be encouraged, if necessary with government assistance, in order to improve the understanding of the potential economic benefits as well as the required technology. This would greatly improve the options available if in the future the price and availability of offshore, imported crude oil exerts severe constraints on supplies for the Canadian transportation industry.

A successful ethanol industry will require the close alliance of the agricultural industry (grain farmers and feedlot managers), the alcohol producers, the oil refiners, the distributors, the vehicle manufacturers, both federal and provincial governments, the marketer and ultimately the consumer. Ethanol production and distribution will have to be just one part of a fully integrated system in order to minimize the risks associated with the development of a new industry and, at the same time, maximize the returns.

If Canadians approach the concept of an ethanol industry with more caution than was exercised in attempts by other countries, we may determine with much less capital expense the bona fide potential for an ethanol industry in Canada. To fully examine the risks and opportunities that would accompany the institution of alcohol fuels across Canada, further research and development spending will be required. To prevent excessive outlays of public and government funds, developing a commercial-size plant involving all the stakeholders and determining, with the least amount of government funding possible, the viability of ethanol as a fuel for Canadians

Figure 3.8

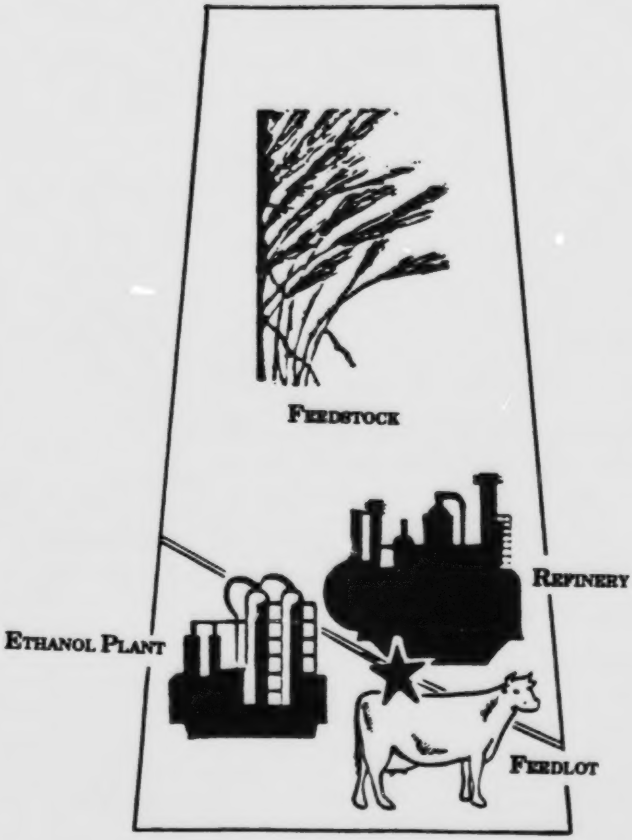
Potential Sites for
"The Commercial Experiment"


ETHANOL PLANT
PIPELINE
ETHANOL PLANT, MINNEDOSA, MB
FORD FFV TEST VEHICLE
TAYLOR
PetroCanada
Feedstock:
Peace Region
134 Barley Acres
Beef: 32,000 Head
CALGARY
Turbo
Feedstock:
Crop District 3
943 Barley Acres
Beef: 214,000 Head
EDMONTON
Imperial
Feedstock:
Crop District 5
1160 Barley Acres
Beef: 246,000 Head
REGINA
Consumers
Cooperative
Feedstock:
Divison 5
123 Barley Acres
1319 Wheat Acres
Beef: 84,000 Head
OAKVILLE
PetroCanada
Feedstock:
West Ont.
478 Corn Acres
Beef: 125,000 Head
MONTREAL
Shell Canada
(Gulf Canada)
Feedstock:
S. St. Lawrence
1085 Corn Acres
Beef: 63,000 Head

SOURCE: Canadian Energy Research Institute.

Figure 3.9

Regina Integrated Unit


Feedstock
Refinery
Ethanol Plant
Feedlot

SOURCE: Canadian Energy Research Institute.

may prove less costly than funding numerous research projects across Canada. To suggest the answer can be determined by economics alone may prove naive if future environmental concerns culminate in the need for oxygenated gasolines.

Figure 3.8 is a map which suggests six sites in Canada that may be ideally situated for the development of an integrated ethanol facility based on their proximity to an oil refinery, a feedstock source, a large enough beef population to support a feedlot using the animal feed by-product, and an assured retail market for distribution to the motor fuel users. Though in all likelihood there are other viable locations in Canada which could support a plant of between 50 and 100 million litres per year capacity, the sites selected were Montreal, Quebec; Oakville, Ontario; Regina, Saskatchewan; Edmonton and Balzac, Alberta; and Taylor, British Columbia. These sites were chosen on the basis of their proximity to a feedstock source as well as a beef population for the by-product, an oil refinery for blending purposes, and a pipeline for transporting the final product (see Figure 3.9). The refinery names on the map are suggestions only as to the players who might be approached in becoming involved in this commercial experiment.

The farmers in the given regions could experiment with feedstocks and research the development of a high starch, low protein grain, with high tonnage yields per acre that could be dedicated solely to ethanol production. At the same time, the refiners could experiment with tailoring their product to meet CGSB standards and the distributors could test different methods of transporting alcohol fuels. Researchers involved in the development of the enzyme necessary to convert cellulose to glucose could be hired to take part in developing an alcohol fuel industry for Canada. The flexible fuel automobile manufacturers must also be involved in such a way that the fuel developed will enhance the value of their cars to the consumer, with government fleet vehicles being used for testing purposes.

If an ethanol project is joint-ventured with an oil refinery and a feedlot for a specified time period, and if enough capital is invested to assure each participant a fair rate of return during the experimental stages, methods may be determined to lower production costs as well as to solve many of the existing problems associated with an ethanol industry. In all fairness to the established pioneers and their investments in this industry, they should be invited as participants in such an experiment. Perhaps it is time to step from the empirical, experimental stage to the practical and determine if economically, socially and environmentally there is a commercial future in Canada for ethanol as an alternative transportation fuel.

Footnotes

[1] United States Department of Energy, Assessments of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector, Progress Report One: Context and Analytical Framework (Washington, D.C.: January 1988), p. C-4

[2] Ibid, p. C-5.

[3] World Bank, Alcohol Production from Biomass in the Developing Countries (Washington, D.C.: September 1980), p. 5.

[4] Ibid., p. 5.

[5] Ibid., p. 9.

[6] Ibid., p. 8.

[7] Ibid., p. 5.

[8] Ibid., p. 6.

[9] Energy, Mines and Resources Canada, Gasohol and Propane Fleet Test, prepared by N. Bercuson, D. Mathers, N. Bourdon, L. Kozalk (Winnipeg, Manitoba: Industrial Technology/Manitoba Research Council, March 1983), p. 39.

[10] Ford Motor Company of Canada, "News From the World of Ford" (Milton, Ontario: October 14, 1987), p. 1.

[11] International Energy Agency, Alcohols and alcohol blends as motor fuels, prepared by The Swedish Motor Fuel Technology Co. (Sweden: October 1986), p. 6:13.

[12] United States Department of Agriculture, Fuel Ethanol and Agriculture: An Economic Assessment (Washington, D.C.: U.S. Government Printing Office, August 1986), p. 4.

[13] Ibid., p.4

[14] Energy, Mines and Resources Canada, Alcohol Additives, A New Opportunity In Transportation Fuels (Ottawa: Queens Printer, 1986), p. 12.

[15] Interview with Hank Krech, St. Lawrence Starch Limited, Mississauga, Ontario, May 20, 1988.

[16] United States, Environmental Protection Agency, Guidance on Estimating Motor Vehicle Emission Reductions From The Use of Alternative Fuels. Prepared by the Emission Control Technology Division (Ann Arbor, Michigan: January 29, 1988), p. 10.

[17] Ibid., p. 10.

[18] Ibid., pp. 10, 11.

[19] United States, National Advisory Panel on Cost-Effectiveness of Fuel Ethanol Production, Final Report (Washington, D.C.: November 1987), p. 4-18.

[20] The Royal Society of Canada, Lead In Gasoline, Alternatives To Lead In Gasoline, prepared by the Commission On Lead In The Environment (Ottawa: February 1986), p. 26.

[21] International Energy Agency, Alcohols and alcohol blends as motor fuels, prepared by the Swedish Motor Fuel Technology Co. (Sweden: Swedish National Board for Technical Development, October 1986), p. 9:4.

[22] Ibid., p. 9:5.

[23] Ibid., p. 9:12.

[24] Ibid., p. 9:11.

[25] Ibid., p. 9:9.

[26] St. Lawrence Starch Limited, Phase I: Pre-feasibility Study For A Comprehensive Alcohol Study For The Province Of Alberta, prepared for Alberta Agricultural Processing Development Branch, Alberta Agricultural Marketing Services Division, November 1986, p. 8.

[27] Canadian Petroleum Association, Statistical Handbook, (Calgary, Alberta: May 1987), Section VIII, Table 3B.

[28] Unless otherwise indicated, all prices referenced are in $1988 Cdn.

[29] Mr. Don O'Connor, the Manager of the Alcohol Fuel Division for Mohawk Oil Co. Ltd., has suggested their product "Premium Plus" provides a marketing advantage of 1¢/litre.

[30] Energy, Mines and Resources Canada, Optimized Linear Program Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries, prepared by Hycarb Engineering Ltd. (Ottawa: Energy, Mines and Resources Canada, March 1986), p. VI-16.

[31] Regarding the 10 mm litre per year plant, Mr. Don O'Connor of Mohawk suggests some of the latest capital cost estimates he has seen have been as low as $7.5 million.

[32] The Winnipeg futures price is actually for grain out of Thunderbay. Mr. Don O'Connor of Mohawk Oil suggested the ethanol producer buying directly from the farmer could save approximately $10-$17/tonne in elevator fees (in and out) for transportation.

Chapter 4

METHANOL

4.1 Introduction

Canada is one of the largest producers of methanol in the world and has enjoyed a reasonably assured export market for the excess production (see Figure 4.1). Until recently, Canadian producers have competed in a world market characterized by surplus capacity, where actual market prices for methanol fluctuated widely, although production costs did not.

The expansion in worldwide capacity that occurred in the 1970s created an uncertain market situation for Canadian producers. To aggravate the situation, new plants came on stream in third world countries which enjoyed the benefits of lower natural gas and labour costs and artificial exchange rates. The result was increased competition from the Middle East, Eastern Europe and Latin America which reduced the export markets for Canadian methanol manufacturers. Until the turnaround about a year ago, Alberta Gas Chemicals Ltd., Celanese Canada Ltd. and Ocelot Industries Ltd., Canada's three world-scale producers, were greatly in need of more diverse markets for their products. However, with the continued growth of the formaldehyde and MTBE markets, Canada's methanol producers have experienced considerable growth and expansion in their markets.

Oversupply is, however, still a concern with plant restart-ups not only in Canada but Malaysia, Brazil and United States. Another concern confronting Canada's methanol producers is when, and exactly where, the product from the new 250 million gallon per year Punta Arenas Chilean plant will enter the North American market.

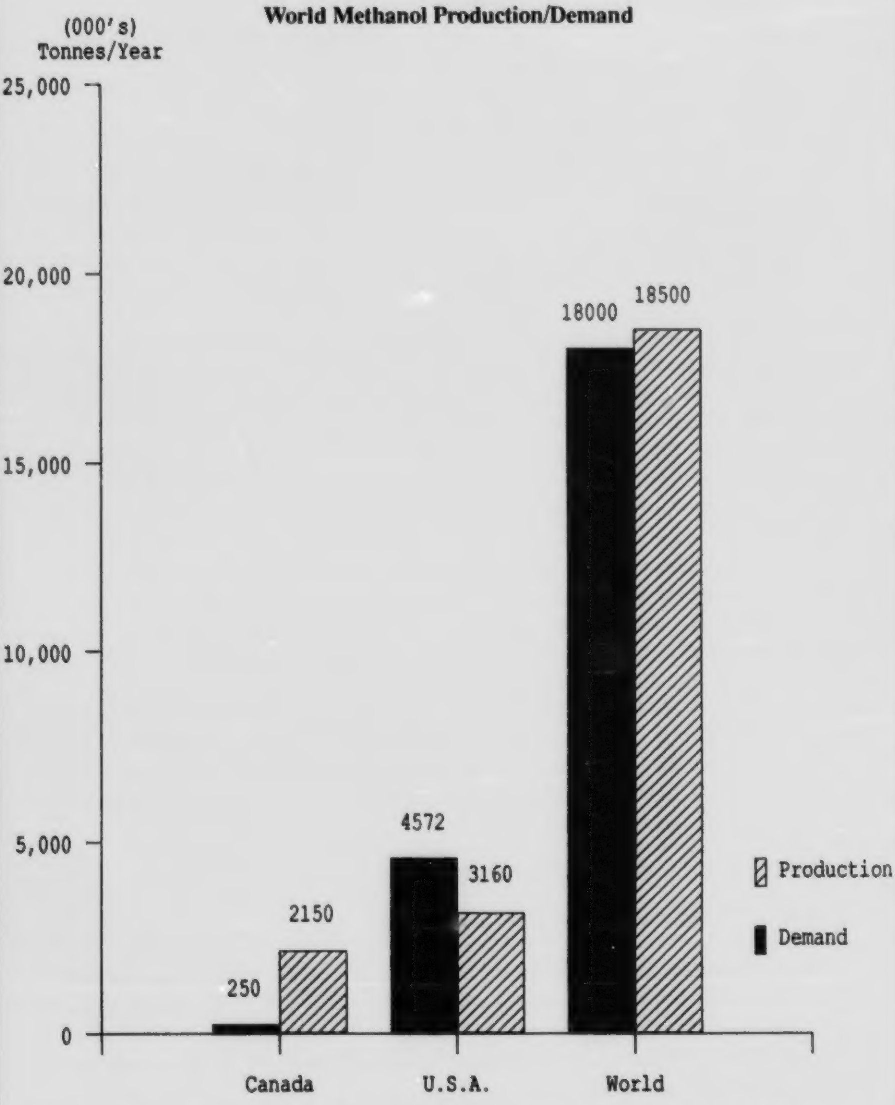
4.2 Methanol: Technical Assessment

4.2.1 Composition and Characteristics

Methanol, a simple organic alcohol, is a clear, colorless, toxic liquid which is miscible with water, ether and other alcohols. It is currently used as a solvent, a chemical feedstock and a gasoline extender. Methanol is produced from synthesis gas (syngas) which consists of carbon monoxide, carbon dioxide and hydrogen.

Figure 4.1

World Methanol Production/Demand



SOURCE: COFA: Presentation to Canadian Gas Association, May 18, 1988.

Table A.1 highlights the physical characteristics of methanol. Fuel system requirements for metals and elastomers for both ethanol and methanol differ from those required by gasoline. Also, like ethanol, methanol has a high flashpoint with wide flammability limits. As a result, neat methanol could produce flammable mixtures in the vapour space of fuel tanks, a definite safety hazard. This can be solved by either adding gasoline components to the fuel or installing flame arresters in the filler tube on vehicles using these alcohols, as most ignition sources tend to be external to the fuel tank.

Assuming equal engine efficiency, methanol's energy storage density would require a fuel tank twice as large as a gasoline tank to fuel a vehicle over the same distance. As methanol weighs approximately the same as gasoline, the fuel storage weight would also be twice that of a quantity of gasoline with the equivalent energy efficiency.[1]

4.2.2 Production

As stated previously, methanol (CH_3OH) can be made using several alternative processes from a variety of feedstocks. Coal, peat and other organic residuals, as well as wood or grass crops, can be gasified and then synthesized to produce methyl alcohol. In Canada, however, all production is derived from the processing of natural gas.

As noted in 4.2.1, methanol is produced from synthesis gas. In Canada, using coal, biomass or agricultural wastes as feedstocks to produce methanol would require a more complex conversion process than producing methanol from natural gas. As this would result in higher production costs, Canadian methanol producers use natural gas as the feedstock for syngas. However, because the methanol producers must negotiate gas prices with the gas producers, and as 80 percent of their production costs are attributed to natural gas; Canadian methanol producers do not consider natural gas inexpensive.

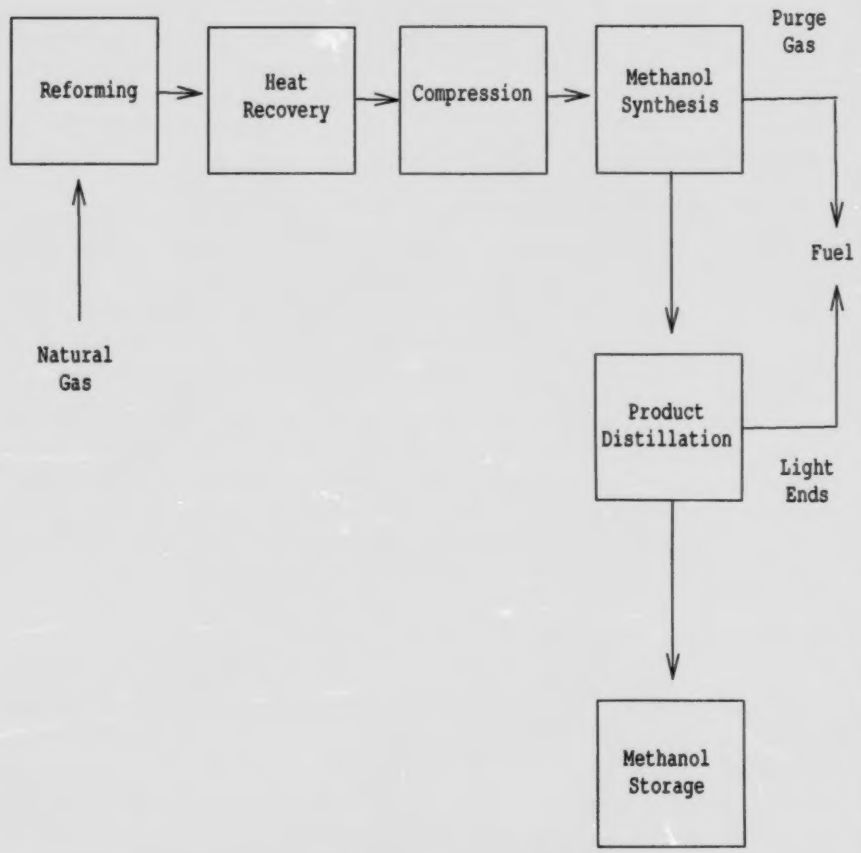
The technologies for producing methanol follow.

4.2.2.1 Methanol from Natural Gas

Canada possesses large reserves of natural gas. As direct utilization of this energy source tends to be "inconvenient" due to storage, handling and application problems, conversion to a liquid fuel could prove beneficial in alleviating these problems while simultaneously providing an alternate fuel source. The bulk of methanol produced in Canada today is derived from methane, the main component of natural gas, via a two-stage process involving certain basic steps (see Figure 4.2 and Figure 4.3):

Figure 4.2

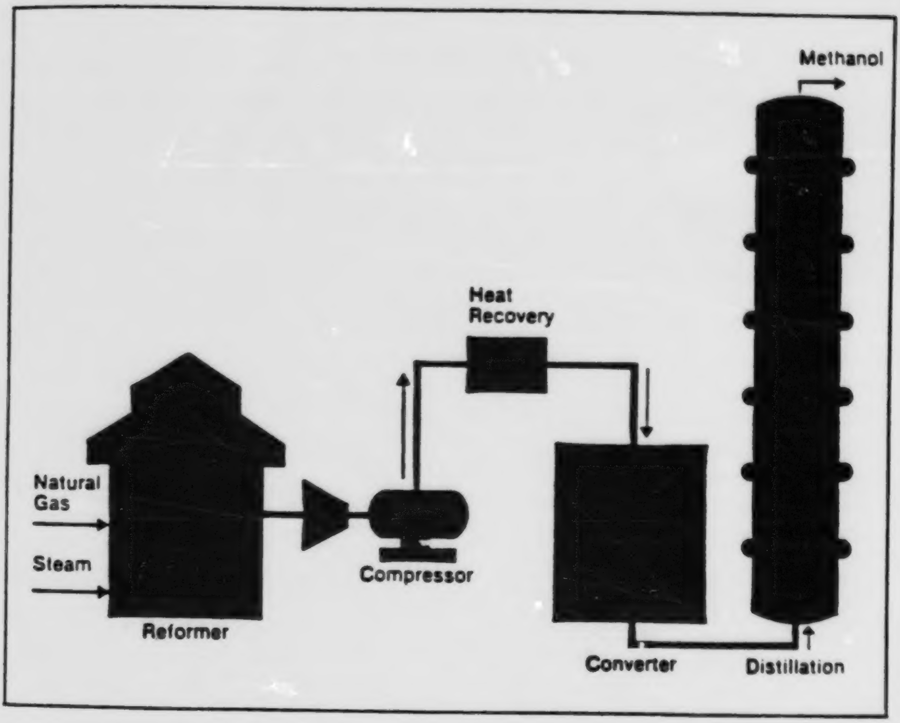
Natural Gas to Methanol


Reforming
Heat Recovery
Compression
Methanol Synthesis
Purge Gas
Fuel
Natural Gas
Product Distillation
Light Ends
Methanol Storage

SOURCE: DM International, Production of Methanol From a Combination of Wood and Natural Gas Feedstocks, presented at the First International Conference on Fuel Methanol (Houston, Texas: October 1982).

Figure 4.3

Simplified Process Diagram
for Methanol


Methanol
Heat Recovery
Natural Gas
Steam
Reformer
Compressor
Converter
Distillation

SOURCE: Celanese Canada Inc., pamphlet.

- Sulphur is removed from the natural gas and impurities from the water feed.

- Gas and steam are fed into a reformer where the natural gas and steam are catalytically reformed into synthesis gas.

- The synthesis gas is dried, cooled and compressed, then fed to a converter.

- In the converter, these gases are reacted under pressure in the presence of a catalyst to form methanol and water.

- Methanol is removed from this solution via distillation.

The chemical formulas which illustrate the above process are:

$$\underset{\text{methane}}{CH_4} + \underset{\text{steam}}{H_2O} \longrightarrow \overset{\text{(Synthesis)}}{\underset{\text{carbon monoxide}}{CO}} + \underset{\text{hydrogen}}{3H_2} \tag{1}$$

$$\underset{\text{carbon monoxide}}{CO} + \underset{\text{hydrogen}}{2H_2} \longrightarrow \underset{\text{methanol}}{CH_3OH} \tag{2}$$

4.2.2.2 Methanol from Coal

Coal liquefaction may well prove beneficial to Canadians in the future as domestic coal reserves are immense, representing the largest proven reserves of any energy resource in Canada. "Recent estimates indicate that domestic coal reserves contain 2.3 times the combined energy of all Canada's other non-renewable energy resources."[2]

Conversion technologies for producing methanol from coal involve a number of phases:

- Preparation: The coal is prepared by grinding it to a specific size and adding water to form a slurry, allowing it to be pumped into a gasifier.

- Gasification: High pressure is applied to the slurry to allow for catalytic conversion into a gas. Much of the waste heat that is required in this phase is recovered as steam. The particulates of ash in the synthesis gas are removed via scrubbing.

- Purification: CO_2 and H_2S, unwanted products of the reactions in the gasification process, are removed by scrubbing with an appropriate alkaline mixture, leaving the syngas as a mixture of CO and H_2.

Coal-to-methanol conversion plants are based upon the process whereby syngas is passed over catalysts at high temperature and pressure to accelerate methanol formation. The two chemical reactions involved are:

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{hydrogen}}{2H_2} \longrightarrow \underset{\text{methanol}}{CH_3OH} \qquad (1)$$

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{hydrogen}}{H_2} \rightleftharpoons \underset{\text{carbon monoxide}}{CO} + \underset{\text{water}}{H_2O} \qquad (2)$$

The first reaction produces the methanol and the second reaction, going left to right, removes any CO_2 which is present and prevents the removal of CO by reversing the reaction. Specially designed catalysts are used to produce these reactions (see Figure 4.4 and Figure 4.5).

Gasification technologies for various coals are dependent upon their reactivity to the gasification media--oxygen, steam and carbon dioxide.[3] The "Lurgi-fixed bed" gasifier is the only commercially recognized pressurized gasifier; however, as recently as 1983-84, the first "Texaco entrained phase" gasifiers with coal-water slurry feed started commercial methanol production in the U.S.[4] Other promising gasification technologies, identified in the International Energy Agency's publication, Alcohols and alcohol blends as motor fuels, are the "fluidized bed Winkler," the "entrained phase Koppers-Totzek," the "U-Gas gasifier," and the "Westinghouse Gasifier."

4.2.2.3 Methanol From Biomass

Methanol, historically referred to as wood alcohol, can be produced from renewable feedstocks such as wood or agricultural and municipal wastes which can also be used to produce synthesis gas. This conversion procedure involves shredding biomass, then heating it at high temperatures in a limited quantity of oxygen. Figure 4.6 is a block diagram illustrating the sequence of processing steps required to convert biomass to methanol.

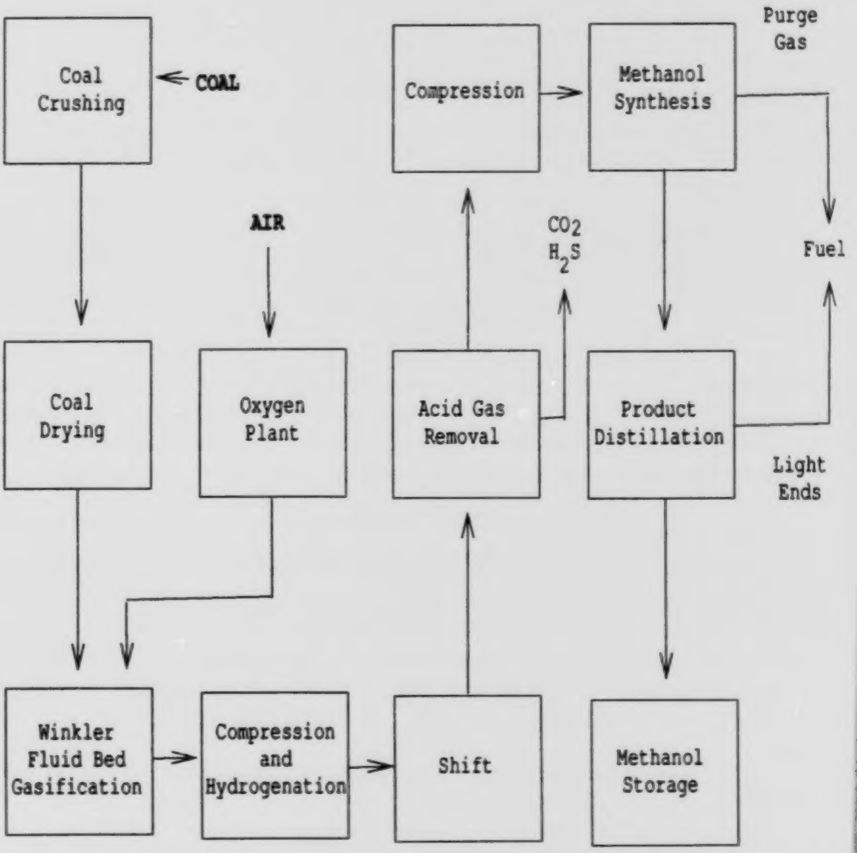
The chemical reactions describing the formation of methanol from biomass are:

$$\underset{\text{carbon monoxide}}{CO} + \underset{\text{hydrogen}}{2H_2} = \underset{\text{methanol}}{CH_3OH} \qquad (1)$$

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{hydrogen}}{3H_2} = \underset{\text{methanol}}{CH_3OH} + \underset{\text{water}}{H_2O} \qquad (2)$$

Figure 4.4

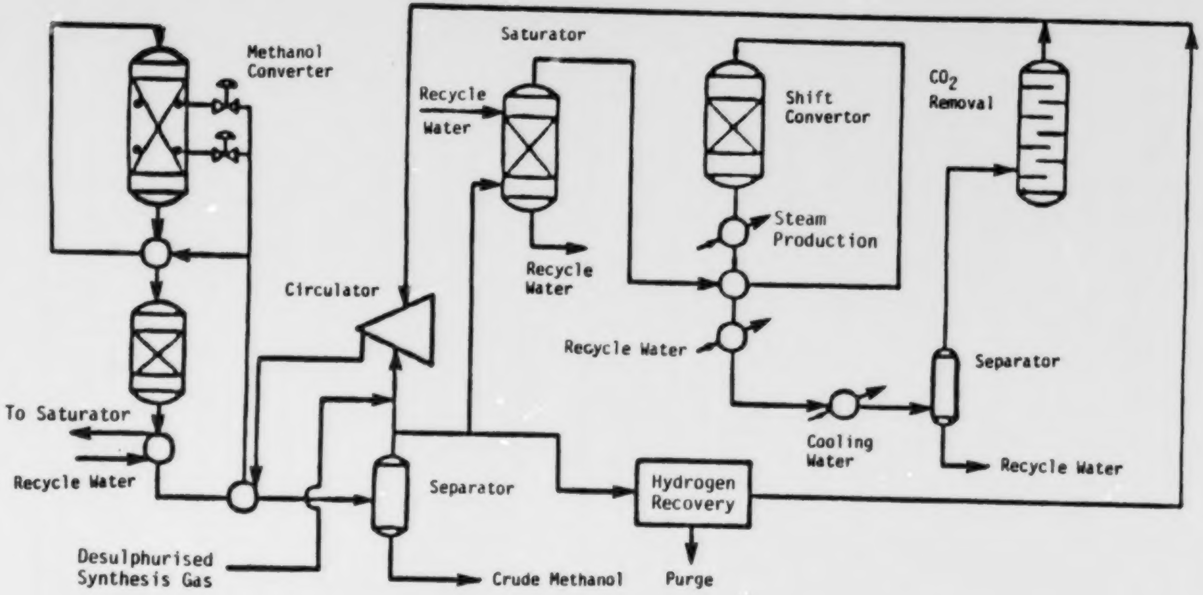
Coal to Methanol


Coal Crushing
COAL
Compression
Methanol Synthesis
Purge Gas
Fuel
AIR
CO2
H2S
Coal Drying
Oxygen Plant
Acid Gas Removal
Product Distillation
Light Ends
Winkler Fluid Bed Gasification
Compression and Hydrogenation
Shift
Methanol Storage

SOURCE: DM International, Production of Methanol From a Combination of Wood and Natural Gas Feedstocks, presented at the First International Conference Fuel Methanol (Houston, Texas: October 1982).

Figure 4.5

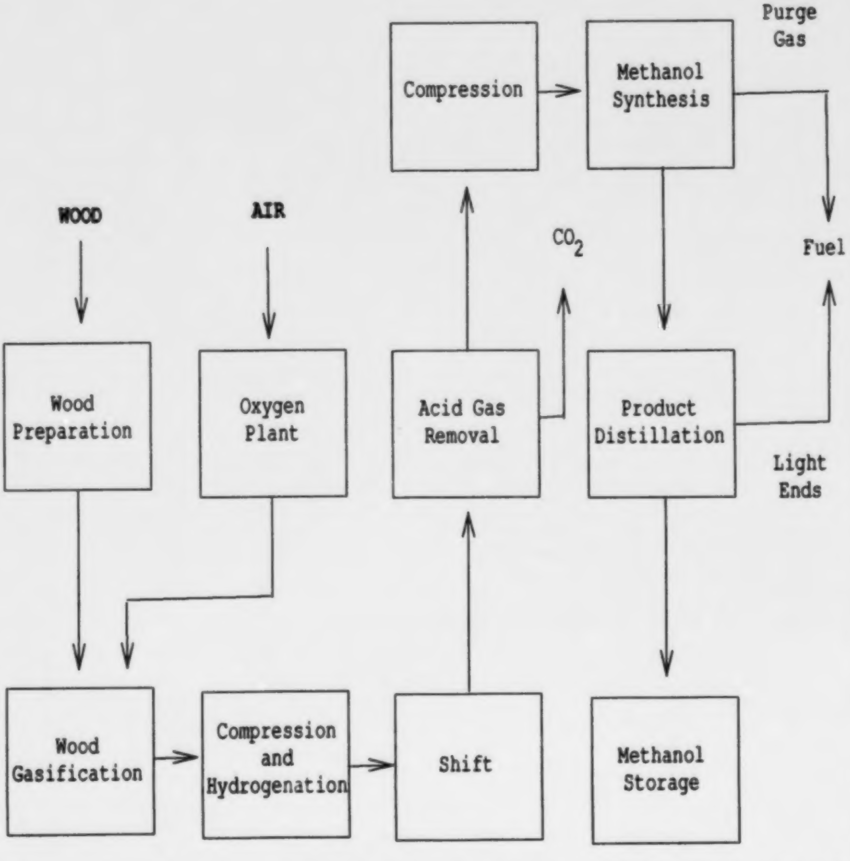
ICI Dual Cycle Methanol Process for Coal-Based Synthesis Gas


Methanol Converter
Saturator
Recycle Water
Shift Convertor
CO_2 Removal
Steam Production
Recycle Water
Circulator
Recycle Water
Separator
To Saturator
Cooling Water
Recycle Water
Separator
Hydrogen Recovery
Recycle Water
Desulphurised Synthesis Gas
Crude Methanol
Purge

SOURCE: International Energy Agency, Alcohols and alcohol blends as motor fuels, Vol. II A (Stockholm, Sweden: October 1986), p. 3:20.

Figure 4.6

Wood to Methanol


Purge Gas
Compression
Methanol Synthesis
WOOD
AIR
CO_2
Fuel
Wood Preparation
Oxygen Plant
Acid Gas Removal
Product Distillation
Light Ends
Wood Gasification
Compression and Hydrogenation
Shift
Methanol Storage

SOURCE: DM International, Production of Methanol From a Combination of Wood and Natural Gas Feedstocks, presented at the First International Conference o Fuel Methanol (Houston, Texas: October 1982).

4.2.2.4 Methanol from Combined Feedstocks

During the oxygen/steam-gasification process, various feedstocks give hydrogen/carbon monoxide ratios lower than those desired. However, steam reforming of natural gas actually yields a high ratio. Gas consumption adjustment may be attained by rejection or removal of the CO_2, adding hydrogen from an alternate source by combining natural gas and heavy oil or solid feedstocks. As Canada has abundant feedstock resources, a number of processes have been researched, one of which is a hydrogen addition through electrolysis, along with the simultaneous oxygen production required for the gasification of the solid feedstock (peat or wood). Combinations of natural gas and peat feedstocks with and without CO_2 removal have also been explored. Optimal production may result from a combination of these processes in an integrated plant (see Figure 4.7). In spite of improved efficiency and lower investment costs, however, the methanol production costs from these new processes are higher than processing from natural gas.[5]

4.2.3 Uses as a Petroleum Substitute

Methanol, a major chemical product used to make formaldehyde and solvents and which forms the raw material in the manufacture of many other chemicals, is also of interest to the transportation sector because of its high octane rating (ranging from 99 as a "neat" fuel to 120 in blends).

There are four possible "automotive" fuel options open to Canada's methanol producers:

(i) as a feedstock in the Mobil methanol-to-gasoline process;

(ii) as a feedstock in gasoline blends along with a cosolvent (ethanol, isopropanol, isobutanol and tertiary butanol);

(iii) as a raw material in the production of methyl tertiary butyl ether (MTBE); and

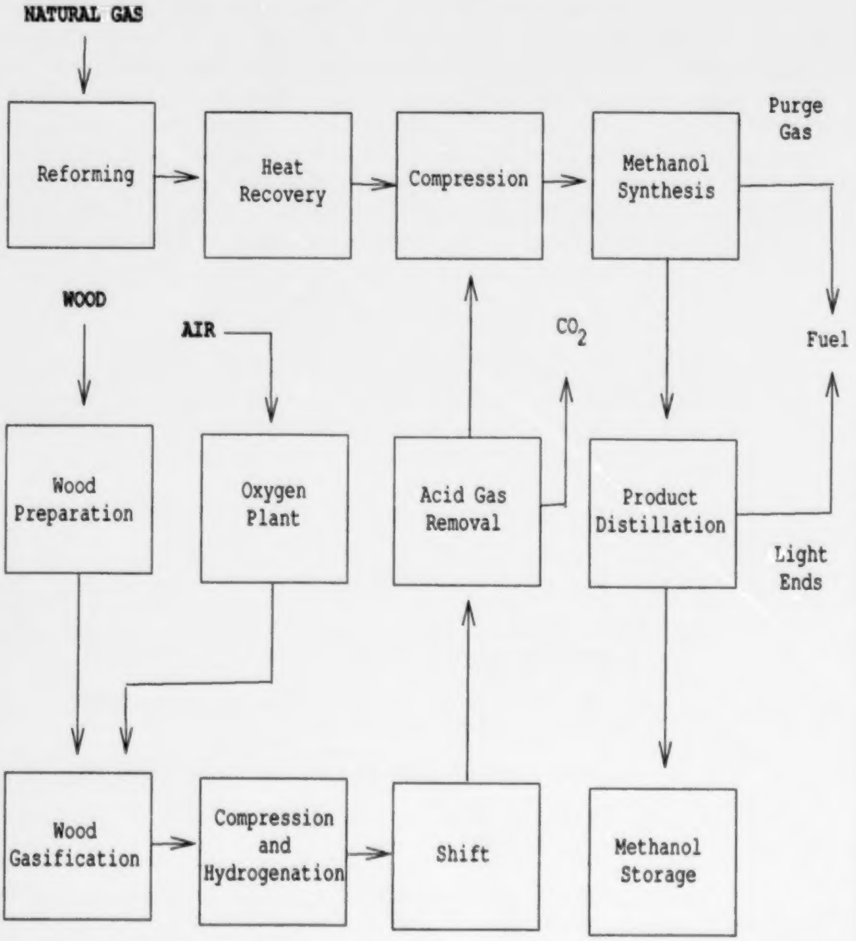
(iv) as a "neat" alternate fuel for gasoline and/or diesel fuel.

4.2.3.1 Mobil's Methanol-to-Gasoline Process (MTG Process)

Through research designed to develop a wide variety of new zeolite catalysts for use in petroleum refining and petrochemical processes, Mobil discovered that methanol could be converted to high octane gasoline using a proprietary zeolite catalyst. In January 1975, research was initiated to develop the Mobil methanol-to-gasoline process. This process suggested a new method of converting coal to high octane gasoline represented by the following chemical reaction:

Figure 4.7

Hybrid Scheme Combinations Feedstocks


NATURAL GAS
Reforming
Heat Recovery
Compression
Methanol Synthesis
Purge Gas
WOOD
AIR
CO_2
Fuel
Wood Preparation
Oxygen Plant
Acid Gas Removal
Product Distillation
Light Ends
Wood Gasification
Compression and Hydrogenation
Shift
Methanol Storage

SOURCE: DM International, Production of Methanol From a Combination of Wood and Natural Gas Feedstocks, presented at the First International Conference o Fuel Methanol (Houston, Texas: October 1982).

$$nCH_3O \longrightarrow (CH_2)_n + H_2O$$

The hydrocarbons produced from this highly selective process consist primarily of high octane gasoline with smaller amounts of liquid propane gas (LPG-C_3 and C_4) and fuel gas (C_1 and C_2). Alkalating the C_3 and C_4 olefins with the isobutane produced in the process further increases the gasoline yield. The gasoline produced is predominantly composed of methyl-substituted aromatics and isoparaffins.[6] The unleaded gasoline produced burns more cleanly than conventional gasoline, as it contains neither nitrogen nor sulphur. Approximately 1.6 cubic metres of natural gas is required to produce 1 cubic metre of gasoline from methanol, with the gasoline containing about 83 percent of the energy content of the crude methanol.

However, this process does invoke added costs and unavoidable energy losses involving additional need of driving energy and an overall loss of liquid fuel to gaseous products. According to the publication, "Alcohols and alcohol blends as motor fuels" published by the International Energy Agency, development efforts by Mobil R & D Co. to convert syngas directly to hydrocarbon motor fuels were said to be unsuccessful due to low yields and low quality.[7] Environmentally, a potential problem with the MTG process is the presence of durene which can crystalize in the carburetor and cause clogging.[8] However, the durene could be distilled and hydrogenated.

4.2.3.2 Methanol in Gasoline Blends

Methanol has a strong affinity to water. It is this characteristic which makes gasoline blended with only methanol an unsatisfactory fuel. The presence of any water in the gasoline would cause phase separation of the methanol and gasoline into distinct layers. This separation, however, can be prevented by the addition of other alcohols, or cosolvents, to stabilize the blend. If low-level methanol-gasoline blends are to be utilized as fuels, careful blending controls will be necessary.

Until recently, Mohawk Oil Co. Ltd. was marketing an alcohol blend under the name "EM Unleaded." This fuel, known in the United States as the "Dupont Waiver" blend, consists of 5 percent methanol, 3 percent ethanol and 92 percent unleaded gasoline. However, in recognition of the current leaning of the automobile manufacturers away from low-level methanol blends, Mohawk stopped marketing this blend in favour of its new high octane Premium Plus (5 percent ethanol, 95 percent unleaded gasoline).

4.2.3.3 Methyl Tertiary Butyl Ether (MTBE)

Production of MTBE

Currently, methanol's contribution to motor fuel supplies is mainly as an input in the production of MTBE. This high octane gasoline additive with unique blending properties has recently gained wide acceptance among refiners as a fully fungible octane enhancer.

MTBE is produced by reacting methanol with isobutylene, which itself can be derived from four different sources:[9]

- the C_4 or butane stream produced in an olefin plant, feeding naphtha and/or gas oil;
- the C_4 stream produced in the catalytic cracking unit within a refinery;
- the butanes recovered from associated or non-associated natural gas; and
- tertiary butyl alcohol (TBA).

Presently, the most economical source of isobutylene is the by-product C_4's from naphtha/gas oil steam cracker olefin plants. The C_4 stream contains roughly 40 percent isobutylene.[10] The MTBE plant proposed for Edmonton, Alberta will utilize natural gas-associated feedstock, isomerizing field butanes to isobutane, dehydrogenate to isobutylene and then convert that to MTBE.

Octane Efficiency of MTBE

The typical octane blending properties of MTBE in higher octane gasoline are:[11]

Octanes	Blending Properties
Research (Ron)	117
Motor (Mon)	99
(R + M)/2	108
Front End (Ron 100^0 C)	135

With lead phasedown occurring by the end of 1990, MTBE's 108 (R + M)/2 blending octane makes it a potential octane additive that can be blended inside the refinery with little, if any, distribution limitations on the gasoline product.

In Canada, MTBE is allowed as a blending component in unleaded gasoline in concentrations up to 11 percent. It is interesting to note, however, that the Sun Refining and Marketing Company was recently granted a waiver to blend 15 percent MTBE with unleaded gasoline.[12]

The market potential for MTBE in Canada depends on a number of factors, including:

- the demand for gasoline
- the requirements of Canadian refinery operations;
- the economics of the production of gasoline and alternative forms of octane improvement; and
- the availability of isobutylene.

The Value of MTBE

Table 4.1 below indicates the value of a 10 percent concentration of MTBE when added to gasoline.

TABLE 4.1

PRICING MTBE BASED ON OCTANE VALUE
(Cdn. cents/Litre)

	At 10% Concentration[a]
Unleaded gasoline price	23.00
Value of blend based on octane efficiency	28.55
Value of blend based on price[b]	24.00

SOURCE: Canadian Energy Research Institute.

[a] At a 10% concentration has an octane value 24 percent higher than unleaded gasoline.

[b] The spot price of MTBE on October 3, 1988 was 95 cents per gallon (U.S./U.S.) or 33 cents per litre (Cdn./Cdn.) [(0.9 x 23) + (0.1 x 33)].

As MTBE can be produced from normal butane or a butane mix for approximately 22 to 23 cents per litre, it is also an economically viable octane enhancer.

The Performance of MTBE

Gasolines containing MTBE have been shown to have higher road octanes than hydrocarbon-only gasolines with the same laboratory octane ratings. Although the actual reason for this "octane bonus" is not really known, it is known to be related to the gasoline's front end octane number (FEON).[13] MTBE's exceptionally high FEON blending number, generally in the range of 135 RON, is the result of this chemical's high octane and relatively low boiling point (55° C). The octane bonus from MTBE is dependent on the MTBE concentration. Gasoline containing 10 percent MTBE will act like a hydrocarbon-only gasoline that is one octane number higher.

With both a low boiling point and a lower-than-gasoline RVP, MTBE's unique volatility relationship has made it known not only as an octane enhancer but as a "driveability index improver."[14] Another positive characteristic of MTBE is that it does not foul or plug the fuel ignition used in late model cars, and can actually reduce this problem in many cases.[15]

The Environmental Effects of MTBE

As an oxygenate, MTBE reduces the carbon monoxide (CO) and unburned hydrocarbon emissions in a car's exhaust through fuel enleanment. In addition to these exhaust emission benefits, MTBE also improves evaporative emissions. A comparison of studies ranking atmospheric reactivity of individual compounds shows that MTBE has one of the lowest oxidation rates,[16] implying that the evaporative emissions from gasoline blended with MTBE will likely contribute to less smog buildup in the earth's atmosphere. Regarding toxicity, the effects of MTBE were ranked relatively low, especially when compared with aromatics.

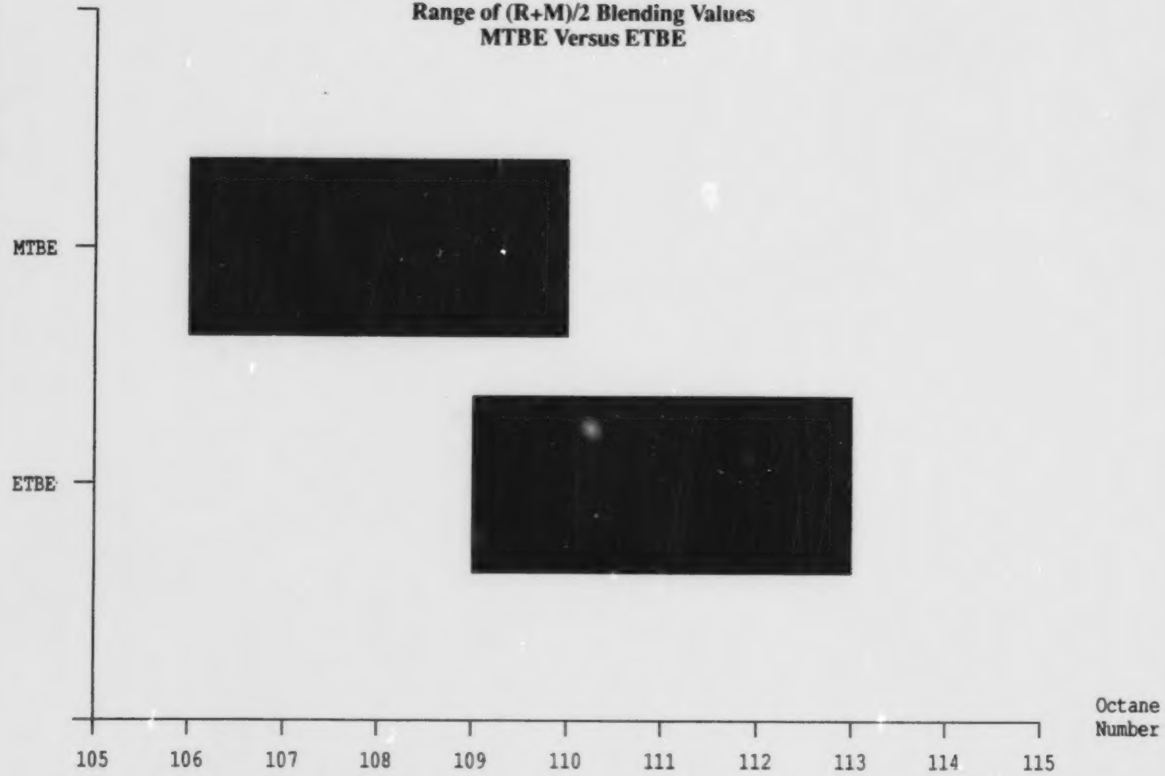
Conclusion

It is MTBE's favourable impact on the distillation curve (which improves cold driveability), its front end octane road bonus (which improves gasoline performance), and its favourable environmental impacts regarding smog reduction in the atmosphere that have refiners currently favouring MTBE above all other oxygenate blending components.

If, however, ethyl tertiary butyl ether (ETBE) commercialization becomes a reality in the United States or Canada, its technical superiority over MTBE with equal or higher octane, lower vapour pressure and higher boiling point may result in some new competition for MTBE (see Figure 4.8).[17]

Figure 4.8

Range of (R+M)/2 Blending Values
MTBE Versus ETBE



SOURCE: Octane Week, October 3, 1988.

	MTBE	ETBE
(R + M)/2	106-110	109-113
Vapour Pressure	10.5 psi	9.6 psi
Blending Vapour Pressure	8.0-8.5 psi	3.9-4.5 psi
Boiling Point	55^0 C	70^0 C

As indicated in Chapter 3, however, ethanol production using current technology would require some sort of assistance (capital investment and/or subsidies) to be economic. Currently, the U.S. Treasury Department and the Internal Revenue Service are considering whether or not ETBE should be eligible for the 60 cent per gallon (U.S./U.S.) federal ethanol blenders tax credit. If granted, MTBE will definitely have some competition.

4.2.3.4 Methanol as a "Neat" Alternative Fuel for Gasoline and/or Diesel Fuel

The automotive industry perceives methanol as the primary candidate for gasoline substitution.[18] Increased requirements for light crude oil imports suggest a need for increasing the use of "neat" substitutes in the fuel industry. This, in turn, would lead to the widescale application of substitute fuels in personal vehicles.

As noted in Chapter 3, the quality of diesel fuels is decreasing as the sulphur and aromatic content of these fuels increases. The cetane number for diesel fuel dropped four full points between 1980 and 1983, while the sulphur content rose from 0.19 to 0.31 percent. Therefore, as the quality of Canada's crude supplies continues to deteriorate, precautionary measures must be undertaken to ensure upgrading of environmentally safe fuels, or alternate fuel sources developed which can be used as effective substitutes.

Near-term substitution emphasis is being placed on methanol replacing road diesel applications. This has resulted primarily in response to the introduction of tougher emission standards. Engine manufacturers in the U.S. are having considerable difficulty designing engines which will meet the stringent diesel emissions standards set to be staged into effect in 1988, 1991 and 1994. As a result, methanol engines are becoming an attractive option for meeting the new standards, especially in overcoming the particulate problem. At least one methanol engine product will be offered for 1990/1991 by a major engine manufacturer.[19]

Low level methanol blends may also provide a market for this alcohol; however, concerns shared by a number of automobile manufacturers may result in these blends being nonviable. Although marketing neat methanol (85 percent methanol with 15 percent gasoline) for automobiles, or straight methanol for buses and trucks, would obviously prove to be the most profitable fuel options for the methanol producers, it has been the rapidly expanding MTBE market which has helped to improve the economics of the methanol industry over this past year. As a complementary substitute for diesel fuel and/or gasoline, increased sales volumes would prove highly beneficial.

4.3 Methanol: Performance and Compatibility With Current Vehicles and the Fuel Distribution System

4.3.1 Compatibility With Current Vehicles

As a normal fuel, methanol can be used in both spark-ignition and diesel engines and, as a clean-burning, high performance fuel, methanol has long been recognized as the fuel for Indianapolis 500 race cars.

Major vehicle and engine manufacturers worldwide are experimenting with methanol vehicles. Although most of these are dedicated vehicles which operate only on methanol, the three major U.S. auto manufacturers are experimenting with "flexible-fuel vehicles" designed to run on any combination of methanol or gasoline fuels. One example, Ford's FFV, has an optical fuel sensor which measures the percentage of methanol in the fuel mixture and adjusts the fuel injection system and spark timing as required to ensure proper blending.

Automotive manufacturers are not adverse to fuel methanol being used in dedicated vehicles. However, there have been suggestions that low-level methanol blends do cause vehicle problems. A statement on fuel use, contained in Chrysler Motors 1987 owner's manual stipulates, "Use of methanol/gasoline blends may result in starting and driveability deterioration and damage to critical fuel system components." Despite this, they are not adverse to methanol/gasoline blends being used in vehicles designed to run on these fuel blends.

Automakers and gasoline retailers are in search of large markets. Unfavourable advertising towards a fuel will, in all likelihood, guide their policies regarding whether or not to promote the use of a fuel. Their objective is and must be to ensure customer satisfaction and confidence. If dedicated vehicles can lead to large economies of scale in methanol fuel and vehicle production, then automakers and retail fuel marketers will promote "neat" methanol; however, if low-level methanol blends result in adverse advertising (which may, in turn, affect customer satisfaction), they will most certainly not promote the use of these fuels.

Straight methanol burns without soot and particulates and emits about half the nitrogen oxide of diesel fuel. This makes it an especially attractive fuel for use in diesel engines. The glow-plug ignition concept, when applied to methanol use in diesel engines, allows for the use of the same fuel injection system, although it must be sized for a larger volume throughput. The result is thermal efficiency equivalent to that of the unmodified diesel engine. Though spark plug life will require improvement, "spark-ignition assist" has been proven to be an efficient method for use in igniting the methanol in diesel engines.

4.3.2 Efficiency

Methanol, like ethanol, exhibits a great resistance towards "knocking." As a blended fuel, methanol has even higher octane values than as a pure alcohol. This can be attributed to methanol's high evaporative cooling effect and autoignition temperatures.

Although methanol has only half the energy content of gasoline, it has 10 to 20 percent better thermal efficiency, which results in improved vehicle performance with as much as 5 to 20 percent more specific power.[20] This results from methanol's lower flame temperature and faster flame speed which releases the heat of combustion more efficiently, resulting in a reduction of heat transfer losses. However, due to methanol's lower energy density, drivers would require about 75 percent more fill-ups for an equivalent driving range if vehicles were not designed with larger fuel tanks.

4.3.3 Power and Driveability

The effects on vehicle power and driveability when using "neat" or "near-neat" methanol as a gasoline or diesel substitute, as well as low-level methanol plus cosolvent in gasoline blends, have been documented in a number of test programs.

An overview of the results and conclusions from existing fleet tests as well as laboratory research data suggests the following:

- In Canada, methanol blended with gasoline is limited to 5 percent by volume. The total oxygen content is limited to 3.7 percent by weight. Due to the limitations regarding driveability and materials compatibility, existing vehicles with spark ignition engines can utilize low-level methanol blends. Blending higher volumes of methanol into the fuel can result in component failures and driveability problems.[21]
- Relatively minor engine modifications are necessary to produce vehicles which can"effectively" use methanol.

- If a "tailored" gasoline is utilized in an M5E3 blend in such a manner as to prevent phase-separation and at the same time meet CGSB specifications, methanol does effectively increase the octane quality of the fuel without causing poor vehicle performance. (Note: A 5 percent methanol/3 percent ethanol mix in regular unleaded gasoline, with an antiknock blending value of approximately 112, adds about two octane units to the resulting blend.)[22]

- Small amounts of water may lead to phase-separation which can, in turn, result in vehicle stalling as well as producing harmful effects on certain metals and elastomers.

- Methanol-fuelled vehicles will require reformulated motor oils to provide adequate corrosion protection and lubrication.

- Higher short-term evaporative emissions result due to methanol's low-end volatility characteristics, unless adjustments are made by backing out some of the butane from the base gasoline.

- The leaning effect of methanol in a blended fuel tends to result in power loss during cold-engine operation. This does not, however, appear to prevent the vehicle from being deemed "acceptable" in carrying out its day-to-day functions. Using special starting systems, or modifying the fuel by blending in volatile hydrocarbons to allow starting at moderately low temperatures, are possible solutions to this problem.

- Low-level methanol blends show little difference from gasoline in their fuel consumption characteristics.

- Vapor-lock is often a problem in very hot climates, as the boiling point of methanol is much lower than that of gasoline. If temperatures are in the 38° C range and the vehicle has been warmed-up, driven, turned-off and left to sit, enough methanol may vaporize to "lock" the fuel lines. Ford solved this condition with an additional low-pressure electric fuel pump and a larger fuel filter.[23]

- Retrofitted or purpose-built cars show both superior performance and reduced harmful emissions in comparison with gasoline-fuelled cars.

- Methanol fuels generally show greater energy efficiency than gasoline.

- Idle performance results from the Ricardo HRCC (high compression, compact chamber) combustion system, when fuelled with methanol, indicate fuel consumption of one-half that of the standard gasoline engine and closer to the range for production diesel engines.[24]

- Data indicate that engines designed to run on methanol tend to be more powerful than engines designed to run on gasoline. Ford tested a 1.6 litre methanol engine which showed 17 percent more brake horsepower at wide-open throttle than a gasoline model. Also, on methanol, the Ford Flexible Fuel Vehicle is almost one second faster in accelerating from 0 to 60 miles per hour than on gasoline. A number of Ford Crown Victorias which were converted to run on an M85 gasoline blend were 14.5 percent faster in accelerating from 0 to 65 miles per hour than the same gasoline powered vehicle.[25]

- Spark ignition and glow plug assisted ignition technology has greatly enhanced the potential benefits of methanol combustion in diesel engines. Adding an ignition improver to alcohols and duplicated-injection engines are other systems being tested to allow for almost complete substitution of alcohol for diesel fuel.

- Partial substitution of diesel fuel by alcohols can be accomplished by dissolving the alcohols, emulsifying the alcohols in diesel fuel, or fumigating the alcohols in the induction air to the engines.[26]

4.3.4 Distribution

4.3.4.1 Transportation

Methanol, like other liquid transportation fuels, can be moved by pipeline, truck, rail and ocean tanker or barge. Trans Mountain Pipe Line Company successfully transported methanol through their pipeline in 1986. Even though the methanol was "batched" through a crude oil pipeline, motor grade methanol was attained at the receiving end of the pipeline. If continuous pipeline transportation of methanol was to occur, however, present pipeline systems would have to be upgraded. Transportation of pure methanol would also require the use of rubber "spheres" to physically separate the products being transported.

As both tankers and barges have been used to transport chemical-grade methanol, shipping fuel-grade methanol should be feasible. Water penetration and phase separation can occur, but these problems may be avoided with routine cleaning and checking of the tanks, pipes and valves or by utilizing dedicated vessels designed to maintain product integrity. According to Ocelot Industries Ltd., their company shipped roughly half a million tonnes of methanol in 1987 without any problems.[27]

Both tank trucks and rail tankers can be used to transport methanol. As with ethanol, though, if either transport vehicle has been used to transport a product other than alcohol, standard industry practice requires that the containers must first be cleaned and purged to prevent contamination.

As methanol contains approximately half the energy of gasoline or diesel fuel, the large-scale production and use of fuel methanol would require storage facilities with almost twice the capacity of that required for gasoline or diesel fuel.

Although methanol has deleterious effects on different materials found in current distribution systems, the long time use of methanol in the chemical industry has resulted in practical solutions to many of the problems encountered in transporting this alcohol. In other words, there is currently sufficient technical experience in transporting alcohols to overcome any of the technical problems which may be encountered with the transportation of blended fuels or fuel alcohols.

4.3.4.2 Blending and Distributing

As noted in Section 3.3.4.2, Canadian oil refiners and marketers are concerned about distributing a blended fuel of different standards which may result in customer dissatisfaction with their products. If the marketing of low-level methanol blends is continued in Canada, refiners would feel more secure about the final product if the actual blending and testing of the fuels occurred at the oil refinery.

However, in circumstances where intermediate transporting by common carrier pipeline or marine transport are required, "tailored" gasoline may have to be prepared at the refinery and both the gasoline and the alcohol shipped separately to the destination terminal to be blended. There remains a concern even then that terminal blending may result in the loss of quality control.

The only other option would be to blend these alcohol fuels on sight at the pump, but this would most likely prove uneconomical. As with gasohol, separate storage tanks would be required for both the alcohol and the "tailored" gasoline. Separate pumps would also be required to disperse the alcohol blend and unless these were designed to provide almost double the delivery rate, total pumping time would increase. As well as being expensive, this method of blending may also leave refiners concerned that the quality of the product would not be maintained and would eventually lead to unsatisfied customers and poor publicity.

Note, however, that in all cases mentioned above, sufficient technical experience with both straight alcohol and low- and high-level alcohol blends currently exists to overcome the technical problems involved with distributing either neat or near-neat methanol or low-level methanol/gasoline blends.

4.4 Methanol: Environmental Impacts

In the United States, environmental considerations and public concern about carbon monoxide levels have reinforced the movement towards alternative fuels. California, in particular, is interested in substituting methanol for a good portion of their diesel fuels to lessen the polluting effects of this fuel. The methanol substitute is likely to be imported largely from Canada. If the United States feels the use of methanol may solve a portion of their pollution problems, it is reasonable that Canadians take a more avid interest in the potential opportunities.

4.4.1 Production Impacts

Reforming natural gas to produce methanol is the least environmentally polluting methanol production process. Not only is the extraction, refining and distribution of natural gas fundamentally pollution-free, the conversion process is relatively simple with few by-products. Converting coal to methanol, on the other hand, has the most deleterious effect on the atmosphere. Using wood as the feedstock to produce methanol results in lower SO_x emissions than the use of coal, but NO_x and particulate emission levels are similar. Conversion of coal to methanol results in the production of not only SO_x, but almost all of the regulated pollutants as well as toxic metals and carcinogenic polycyclic hydrocarbons.[28]

4.4.2 Vehicular Emissions

4.4.2.1 Exhaust Emission With Methanol Blends: HC, CO and NO_x

As described in Section 3.4.2.1 when an oxygenated fuel is fed into the cylinder of a conventional gasoline engine, the combustion effect is as though the mixture were lean. With more oxygen available to complete the combustion than would be the case for straight gasoline, the result is reduced exhaust emission of hydrocarbons and carbon monoxide (CO) but increased nitrogen oxide (NO_x) emissions (see Table 4.2). If, however, the expected average oxygen levels are greater than or less than 3.7 percent, the reduction in exhaust HC and CO emissions as well as the increase in NO_x emissions must be adjusted linearly.[29] In other words, increases in RVP from ASTM type levels which occur when either gasohol or low-level methanol blends have not been made with tailored gasoline result in an increase in exhaust emissions. However, as noted in Section 3.4.2.1, closed-loop vehicles

TABLE 4.2

TECHNOLOGY-SPECIFIC EXHAUST EFFECTS OF BLENDS PERCENT CHANGE FROM GASOLINE
(low and high altitude)

	3.7% Oxygen (10% ethanol or 5% Methanol/Cosolvent Blends)					2.0% Oxygen (11% MTBE Blends)		
	CO			VOC[a]		CO		VOC
Technology	Same RVP	+0.76 PSI[b]	NO$_x$	Same RVP	+0.76 PSI[b]	Same RVP	NO$_x$	Same RVP
Non-Catalyst	-24.5%	-22.8%	+3.8%	-5.5%	-4.2%	-13.2%	+2.1%	-3.0%
Open-Loop Catalyst	-34.9	-33.4	+4.0	-15.6	-14.5%	-18.9	+2.2	-8.4
Closed-Loop	-21.4	-17.2	+8.1	-5.1	-2.4%	-11.6	+4.4	-2.8%

SOURCE: U.S. Environmental Protection Agency, Guidance on Estimating Motor Vehicle Emission Reductions From the Use of Alternative Fuels and Fuel Blends, p. 35.

[a] Volatile organic compounds.
[b] Adjustments to RVP for 75° ambient temperatures.

equipped with an oxygen sensor may compensate for the oxygen present in the fuel and produce lower HC and CO emissions.

Regarding "exhaust" aldehydes and "exhaust" alcohol in methanol blends with up to 3.7 percent oxygen, a recent study by the U.S. Environmental Protection Agency suggests the net effects of these emissions is zero.[30]

4.4.2.2 Evaporative Emissions With Methanol Blends: HC

Adding methanol to a gasoline which has not been tailored generally results in an increased RVP of around 2 to 3 p.s.i. and, unless the base gasoline backs out butane to meet ASTM volatility parameters, higher "diurnal" HC emissions would be experienced. If, however, ASTM standards are met, the lower molecular weight of methanol (32 versus gasoline at 64) would result in a reduction of diurnal evaporative emissions (see Table 4.3).[31]

Vehicles using a methanol blend experience evaporative emissions which are about 15 percent methanol.[32] Unburnt methanol is relatively inactive photochemically. However, the evaporative emissions from methanol contain about ten times more formaldehyde (still relatively small amounts) than gasoline and formaldehyde is photochemically reactive, thus contributing to the ozone formation problem.[33]

Catalyst control systems, designed to reduce formaldehyde emission in current methanol vehicles toward the level of comparable gasoline cars, are currently being developed. In fact, two advanced lean-burn methanol technology vehicles have already demonstrated their ability to meet these emission levels.[34] Overall, methanol exhaust has a low reactivity potential, even with a higher formaldehyde fraction in the methanol exhaust, while gasoline has a medium reactivity potential for forming ozone.[35]

4.4.2.3 Exhaust and Evaporative Emissions With Neat and Near-Neat Methanol

Burning high concentrations of methanol or neat methanol produce both exhaust and evaporative emissions containing high concentrations of methanol. Although elevated levels of formaldehyde may also occur, it should be noted that the presence of gasoline in the blend would also result in significant hydrocarbon emissions.[36]

It is interesting to note that although methanol blends increase the NO_x emissions in relation to the base gasoline, burning neat methanol in methanol-fuelled vehicles may well prove beneficial as a diesel fuel

TABLE 4.3

TECHNOLOGY-SPECIFIC EFFECTS OF 3.7% OXYGEN METHANOL/COSOLVENT BLENDS: EVAPORATIVE VOC[a]

(% change from gasoline including reactivity adjustment)

	11.5 RVP Base		9.0 RVP Base	
	Same RVP	RVP + 0.76	Same RVP	RVP + 0.76
100% Share (no commingling)				
Diurnal				
Carb.	-18.79	+61.89	-18.79	+26.88
F.I.	-18.79	+99.76	-18.79	+28.26
H.S.				
Carb.	-3.19	+12.45	-3.19	+3.37
F.I.	-12.10	+11.90	-12.20	+24.77
50% Share (max. commingling)				
Diurnal				
Carb.	+28.60	+111.4	-2.94	+58.94
F.I.	+50.69	+189.1	-1.64	+68.28
H.S.				
Carb.	+6.90	+24.93	+1.69	+12.33
F.I.	+0.05	+25.92	+6.25	+48.66

SOURCE: U.S. Environmental Protection Agency, Guidance on Estimating Motor Emission Reductions From the Use of Alternative Fuels and Fuel Blends, p. 37.

[a] These effects include adjustments for lower molecular weight of methanol and lower number of carbons/gram relative to gasoline vapour. For hot soak, adjustments for molecular weight are not used, but for carbureted vehicles an adjustment for distillation (% evap @160°F) is included. The no commingling scenarios are based on the Draft Regulatory Impact Analysis, "Control of Gasoline Volatility and Evaporative Emissions from New Motor Vehicles," published in May 1987 by the EPA, and the maximum commingling scenarios adjust the no commingling estimates per the reference from Arco (Arco Letter on Commingling and Fuel Volatility from W. J. West to Charles L. Gray, EPA, February 4, 1985).

F.I. = Fuel Injection.

substitute. The neat methanol fuel produces lower NO_x and particulate emissions than the poorer grade diesel fuels currently being produced. Figure 4.9 illustrates the dramatic drop in particulate emissions from two methanol buses versus a federally certified diesel fuelled transit bus, all of which were part of the California Energy Commission demonstration program in Marin County.[37]

If diesel fuel use is to continue and standards are to be maintained by the transit and trucking industry, the implications will be innumerable. Engine manufacturers can modify existing diesel engines to reduce nitrogen oxide levels, but in so doing would increase the emission of particulates. The reversal is also true; modifying the engines to reduce the NO_x levels would require installing "traps" downstream in the exhaust system to reduce the particulates. These traps would add "several thousands"[38] of dollars in costs to truck prices. As both traps and the need for cleaner diesel fuels will add to the operating and maintenance costs of heavy duty diesel vehicles, heavy duty methanol vehicles may in the end prove less expensive to operate than diesel vehicles.

4.5 Methanol: Health and Safety Hazards

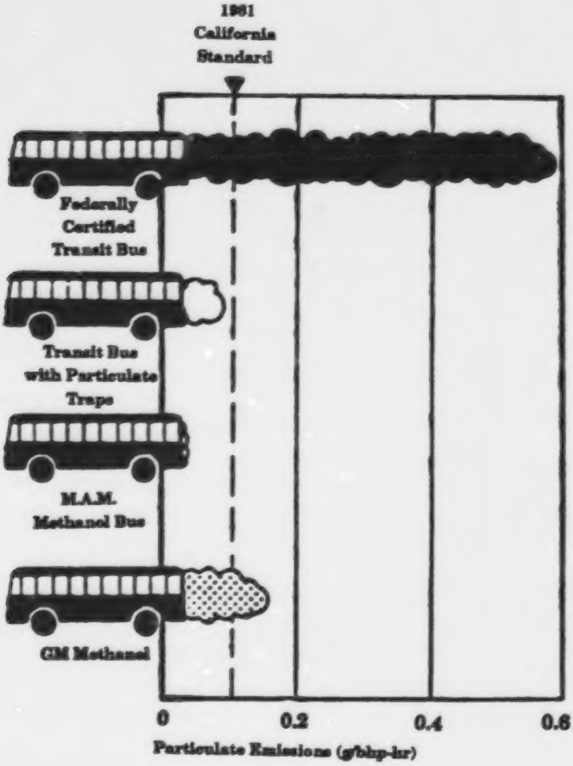
4.5.1 Toxicity

Methanol, like gasoline, is highly toxic and would, therefore, require some form of denaturing (e.g., coloring) before it became widely sold as an automotive fuel. Ingestion of methanol causes permanent damage to the central nervous system, possibly blindness and often death.[39] The effects of methanol at low-level chronic exposure are not as well known. Therefore, research to identify these effects should be determined before major investments are made in the methanol fuel industry. Research analysis performed by the EPA in the United States suggests that methanol would not exceed the lower limits of concern (4.5 milligrams of methanol per cubic metre) specified by the U.S. Occupational Safety and Health Administration under normal moving traffic conditions; on the other hand, severe conditions in garages, for example, could greatly exceed this limit.[40]

Benzene, a known carcinogen, is one of the toxic air contaminants emitted from the exhausts of gasoline and diesel fuelled vehicles. As emissions from methanol vehicles show benzene levels around one-seventh the levels emitted from gasoline, methanol use may prove beneficial in displacing some of the hazardous air quality conditions which are being experienced today.[41]

Figure 4.9

Particulate Emissions Reductions Achievable With Methanol Use in Heavy-Duty Engines



SOURCE: California Energy Commission, Fuels Report, November, 1987.

Formaldehyde is also toxic. At the lower levels of formaldehyde (0.03 milligrams per cubic metre) set by the U.S. Occupational Safety and Health Administration, irritation of the eyes, ears, nose, throat and skin can occur.[42] At higher levels, formaldehyde is suspected of producing carcinogenic effects. Again, the EPA research team found that only under severe conditions such as in roadway tunnels and garages, would the lower limits be exceeded. However, as with ethanol, further research may well be called for if methanol is to become "the" substitute for diesel fuels (see Table 4.4).[43]

4.5.2 Flammability

The physical differences between gasoline, diesel fuel and methanol are important when evaluating the safety hazards which might occur as a result of traffic accidents, transportation, spillage and storage.

Unlike gasoline, which exhibits relatively narrow flammability limits, methanol stored in closed containers is theoretically explosive at temperatures from around 10° C to 40° C. However, methanol's excellent conductive properties reduce the risk of static electricity igniting the vapour which forms above the liquid surface.

4.5.3 Transportation Hazards

Installing flame arresters on vents or adding light hydrocarbons would alleviate the risk involved in storing methanol in vehicle tanks. Further, if the flash points are considered, alcohol spills would be less hazardous when compared to gasoline, but more hazardous than diesel fuel.[44] Although methanol burns without a luminous flame, it does so with lower heat radiation. It should also be noted that there are alcohol-resistant foams available for firefighting purposes.

The effects of methanol spills on terrestrial and aquatic ecosystems appear less serious than those of either gasoline or diesel fuels, as normal biodegradation of this alcohol is more rapid than for either of the hydrocarbons. However, a methanol spill does leave effects on vegetation which remain for at least 1 year, and aquatic ecosystems would also suffer negative effects.

4.6 Methanol: Economic Assessment

The stability and future growth of the methanol industry in Canada may well be tied to the methanol producers' ability to promote the viability of methanol as a useful substitute for a portion of the current gasoline market for use in flexible fuel vehicles, as a chemical feedstock for MTBE, or as a substitute for the poorer grade diesel fuels currently being

TABLE 4.4

MOTOR VEHICLE EMISSIONS CURRENTLY UNDER REVIEW OR IDENTIFIED AS HAZARDOUS OR TOXIC POLLUTANTS

	Fuel				Hazardous Pollutant List			
					State Reg.		Federal Reg.	
Compound	M100	M85	Gasoline	Diesel	Compounds Listed Under AB 1807	Identified as Toxic Under AB 1807	Clean Air Act Candidate Hazardous Air Pollutant	Clean Air Act Listed Hazardous Air Pollutant
Formaldehyde	X	X	X	X	X		X	
Acetaldehyde		X	X	X	X		X	
Benzene		tr	X	X	X	X		X
Xylene		tr			X		X	
Acrolein		tr	X		X		X	
PAH		tr	X				X	
1, 3 Butadiene		tr	X				X	
Gasoline vapours		X[a]	X				X	

SOURCE: California Energy Commission, November 1987.

LEGEND: tr = trace amounts (Denotes reduced levels which are roughly 7 times lower than most levels found for gasoline).
PAH = Polycyclic Aromatic Hydrocarbons.

[a] Measurements show that gasoline vapours associated with M85 are two to four times lower than most levels found for gasoline.

sold. Methanol is unlikely to increase its share of the fuel market through low level methanol/gasoline blends as oil refiners will not market under their own product name fuel blends which are not supported by the automobile manufacturers. As was shown in Table 3.1, a number of automobile manufacturers have indicated their concern for methanol/gasoline blends by discouraging use of these fuels in their owner's manuals.[45]

4.6.1 Demand

Increasing the demand for methanol in the transportation energy sector will involve eliminating the barriers of economic risk to the methanol producers, consumers, distributors and car manufacturers. Methanol prices, which have fluctuated from a low of 8.5 cents per litre in January 1987 to approximately 20 cents per litre in October 1988, will have to stabilize at a competitive price relative to gasoline and diesel fuel.

The demand for methanol has picked up over the past year. The gains have been primarily due to continued expansion in the MTBE and formaldehyde markets. Also, regulating the reduction of lead content in our gasoline is forcing refiners to determine alternative octane enhancers. Although major oil companies have indicated that they have the ability to adapt their processing to internally compensate for the loss in octane, the smaller refiners and blenders may lack the capital resources to make the necessary changes and might therefore rely on octane enhancers such as methanol, ethanol or MTBE.

The near-term economic stability of Canadian methanol producers may well be determined by their ability to competitively supply the requirements of the U.S. transportation fuel market. However, possible restart-ups of previously idled production facilities such as the Hoechst Celanese methanol plant at Clear Lake, Texas, the Allemania methanol plant, and/or the Getty methanol facility at Delaware City may not only inhibit Canadian methanol imports to the U.S. but may also cause methanol prices to decline sharply. A further downward pressure on prices may result from the Chileans targeting the U.S. marketplace with their new production.

There are other influencing factors which may result in increased demand for methanol in the transportation sector. The United States has incorporated a Clean Air Act which has served to promote the use of oxygenates in gasoline blends and neat methanol as a diesel fuel substitute, to attain specified air quality standards. Should Canadians establish a similar national policy, the same adjustments to fuel requirements may create a larger demand for Canada's methanol production and enhance the long-term market prospects for this industry.

The automotive industry is taking a lead role in the transition from a petroleum based fuel society to one capable of incorporating alcohol fuels. The flexible fuel vehicle has greatly enhanced the transition towards alcohol fuel utilization. During the initial transition period, while alcohol fuelling stations may be sparsely situated, the consumer will have the flexibility to switch to gasoline should the need arise. The obvious uncertainty with incorporating commercial use of these cars is that the consumers have the option to use either gasoline or methanol; therefore, the new fuel must first establish consumer acceptance and satisfaction and promote the demand for methanol.

The regional model in Appendix E suggests that, if methanol use in the transportation sector were to increase to where it substitutes for 10 percent of the unleaded gasoline market and as high as 25 percent of the diesel fuel market over the next 10 years, there would be a demand for 11.8 billion litres of methanol by 1998.

4.6.2 Certainty of Supply

Canada possesses some 2746 billion cubic metres[46] of natural gas reserves and 6268 mega tonnes of coal[47] reserves, as well as ample biomass resources. There is little concern, therefore, over the methanol industry being constrained by a feedstock shortage.

Currently, Canadian methanol producers consume 80 billion cubic feet of natural gas annually in producing 10 percent of world methanol production.[48] Though Canada has vast alternative feedstock resources in coal and biomass, the short-term prospects of using either of these to produce methanol appear uneconomical, as the production processes involved are much more capital intensive and would be vying for a spot in a domestic market which is already exporting 85 percent of its production to the U.S., Japan and Europe.

4.6.3 Conversion Costs

Consumer conversion from gasoline to methanol use in vehicles would probably mean either investing in a car with an engine designed for dedicated methanol usage or acquiring a flexible fuel vehicle. Mass production of flexible fuel vehicles for either ethanol or methanol, which is still probably 3 to 5 years away, will conceivably lower the present costs of these vehicles to within $200.00 to $500.00 of those running on straight gasoline.

4.6.4 The Value of Methanol

Determining a value for "fuel-grade" methanol under current market conditions is perplexing. Due to lower inventories in the U.S., plant outages in various parts of the world, a strong demand from the chemical industry, and a rapid increase in the demand for MTBE, methanol prices have risen from a low of 8.5 cents per litre in January 1987 to 20 cents per litre in October 1988. Although methanol prices are tied to the price of gasoline because their feedstock prices (crude oil and natural gas) are directly related, the present market price for methanol is also reflecting its value in the chemical industry. The purity level currently required for "fuel-grade" methanol is less than that required for chemical grade; therefore, it is feasible that lower prices could exist for this alcohol as a fuel, making it more competitive in the energy market.

Table 4.5 suggests that M85 gasoline blends would have to be priced at around 14 cents per litre to be competitive with gasoline. However, it must be noted that this price does not include the additional costs of acquiring a flexible fuel vehicle or the additional costs attributed to the distribution system which would have to be established.

4.6.5 Technological Advancements

As methanol gradually secures a greater percentage of the fuel market, there may well come a time where coal and biomass feedstocks become economical alternatives to natural gas feedstock. Available estimates suggest that it costs between 18 and 24 cents per litre to produce methanol from coal. Although the production technology is fairly well developed, further refinements may be required to bring production costs more in line with conventional gasoline and diesel fuels.

Methanol's fuel efficiency and emission characteristics have not yet been optimized in the current design of the methanol/gasoline compatible engine. Though superior to straight gasoline, particularly regarding emissions, it is because of this slightly degraded performance that some who favour methanol on environmental grounds have objected to flexible fuel vehicles.[49] Further enhancement of these vehicles through additional testing, smog chamber studies and photochemical modeling analysis may provide the necessary enhancement required to inspire the buyers and remove the uncertainty faced by auto manufacturers.

TABLE 4.5

PRICING METHANOL BASED ON FUEL VALUE
(¢/litre)

	M85 As A Gasoline Substitute	M100 As A Diesel Substitute
Unleaded gasoline price	23.00	--
Diesel fuel price	--	21.50
Penalty for lower Btu content	11.62[a]	9.68[b]
Methanol value due to thermal efficiency[c]	13.94	11.61

SOURCE: Canadian Energy Research Institute.

[a] Btu content deficiency in relation to unleaded gasoline (23 x 0.505).
[b] Btu content deficiency in relation to diesel fuel (21.50 x 0.45).
[c] Assumes the entire blended fuel to be 20% more efficient.

4.6.6 An Empirical Analysis of the Methanol Industry

As the three world scale methanol plants currently operating in Canada are all natural gas based, the economic analysis performed in this section relates only to this process of methanol production.

4.6.6.1 Financial Criteria

The financial criteria used to establish the viability of each methanol case analyzed were as defined in Section 3.6.4.1, that is:

- Rate of return on investment; and
- Payout or payback period.

4.6.6.2 Financial Evaluation

Although the two most obvious factors affecting the viability of the Canadian methanol industry are, understandably, the cost of the natural gas feedstock and the market price of methanol, the capital investment requirements and the plant efficiency factor (yield of methanol per thousand cubic feet (Mcf) of natural gas) can also have varying effects on the overall viability of this industry. Following is a brief economic analysis describing the effects of feedstock and product price changes on the methanol industry as well as sensitivities on the capital investment and yield factor.

The hypothetical plant used for this analysis has an annual production capacity of 1 billion litres. The start-up profile used is 0 percent, 90 percent, 95 percent and 100 percent, with a project life of 10 years. Construction of the refinery is assumed to take place in 1988. It is recognized that no methanol plant would normally be built using 100 percent equity. However, as the ratio of debt to equity capital employed and the rate of interest paid on borrowed capital can vary greatly between projects, this ratio was held constant at 0/100 percent in all the cases analyzed.

4.6.6.3 Production Costs

Depending on geographic location, natural gas supplies, treatment of depreciation and overall plant efficiencies, actual production costs can vary considerably among producers. Therefore, it must be recognized that the production costs utilized in this analysis are estimates only, derived from both public and confidential data.

Table 4.6 summarizes the production cost assumptions.

TABLE 4.6

FINANCIAL EVALUATION
PROJECT CHARACTERISTICS
1988-1998
(1 billion litres/year plant)

Project Characteristics	Cdn. ¢/L
Methanol yield (litres/Mcf)	35
Methanol price (¢/L)	20
Production costs (¢/L)	
feedstock	4.3
other fixed plus variable costs	2.7
depreciation	2.7
Natural gas price (Mcf)	$1.50
Debt/equity ratio	0/100
Tax rate (%)	44.8
Discount rate	15%
Project Life (years)	10
Constant Candian dollars Investment assumed made on July 1, 1988.	

SOURCE: Canadian Energy Research Institute.

NOTE: Assumed natural gas price is delivered, and product price of methanol is plant gate. Converting the above to U.S. dollars using $1.25 as the exchange rate:

Methanol price (¢/gal)	60.6
Production costs (¢/gal)	
Feedstock	13.0
Other fixed plus variable costs	8.2
Depreciation	8.2
Natural gas price ($/Mcf)	$1.20

4.6.6.4 Results of the Financial Evaluations

As indicated in Table 4.7, a 5 cent per litre change in product value can have very positive or very detrimental effects on the economics of the project. When natural gas is selling at $1.50 per thousand cubic feet and methanol is marketable at 20 cents per litre, fuel methanol is viable to the methanol producer allowing a rate of return of 29.5 percent. Although at 15 cents per litre producers are still able to maintain a reasonable rate of return (16.9 percent), at 10 cents per litre producers are unable to recover their operating plus capital costs.

Raising or lowering natural gas prices also has a major effect on the project economics (see Figure 4.10). A 50 cent per Mcf increase or decrease in feedstock costs affects the payout by a year and the rate of return by 5 percent. Figures 4.11 and 4.12 indicate the effects on per litre production costs of varying the amount of capital invested in a project versus lower or higher efficiency factors.

As indicated, a $25 million change in initial capital outlay affects the per unit after tax profits by 0.15 cents. Increasing the output per Mcf of natural gas by 20 litres per thousand cubic feet of natural gas adds 1.5 cents per litre to after tax profits.

The analysis performed suggests the market value of methanol and the plant efficiency factor have greater effects on the viability of the methanol industry than do the initial capital outlay or changes in feedstock price.

4.7 Conclusions

Demand levels for methanol in Canada have expanded fairly rapidly over the past year due to the increased markets for MTBE and formaldehyde. This has resulted in a methanol price increase of over 10 cents per litre since January 1987, when methanol producers were receiving under 9 cents per litre for their product and barely recovering their variable costs. At the current market price of 20 cents per litre, methanol producers are prospering. However, stable and competitive prices relative to gasoline and diesel fuel will be required if methanol is to continue to compete with the gasoline and diesel fuels currently being sold in the marketplace.

By the mid-1990s, with lead phased out of our fuels, with flexible fuel vehicles attaining commercial production levels, with gasoline prices increasing, and with diesel quality continually decreasing, methanol may fare well as a gasoline and/or diesel substitute. Although chemical and industrial uses will continue to dominate the demand for this alcohol, fuel

TABLE 4.7

FINANCIAL EVALUATION RESULTS
1988-1998
(1 billion litres/year)

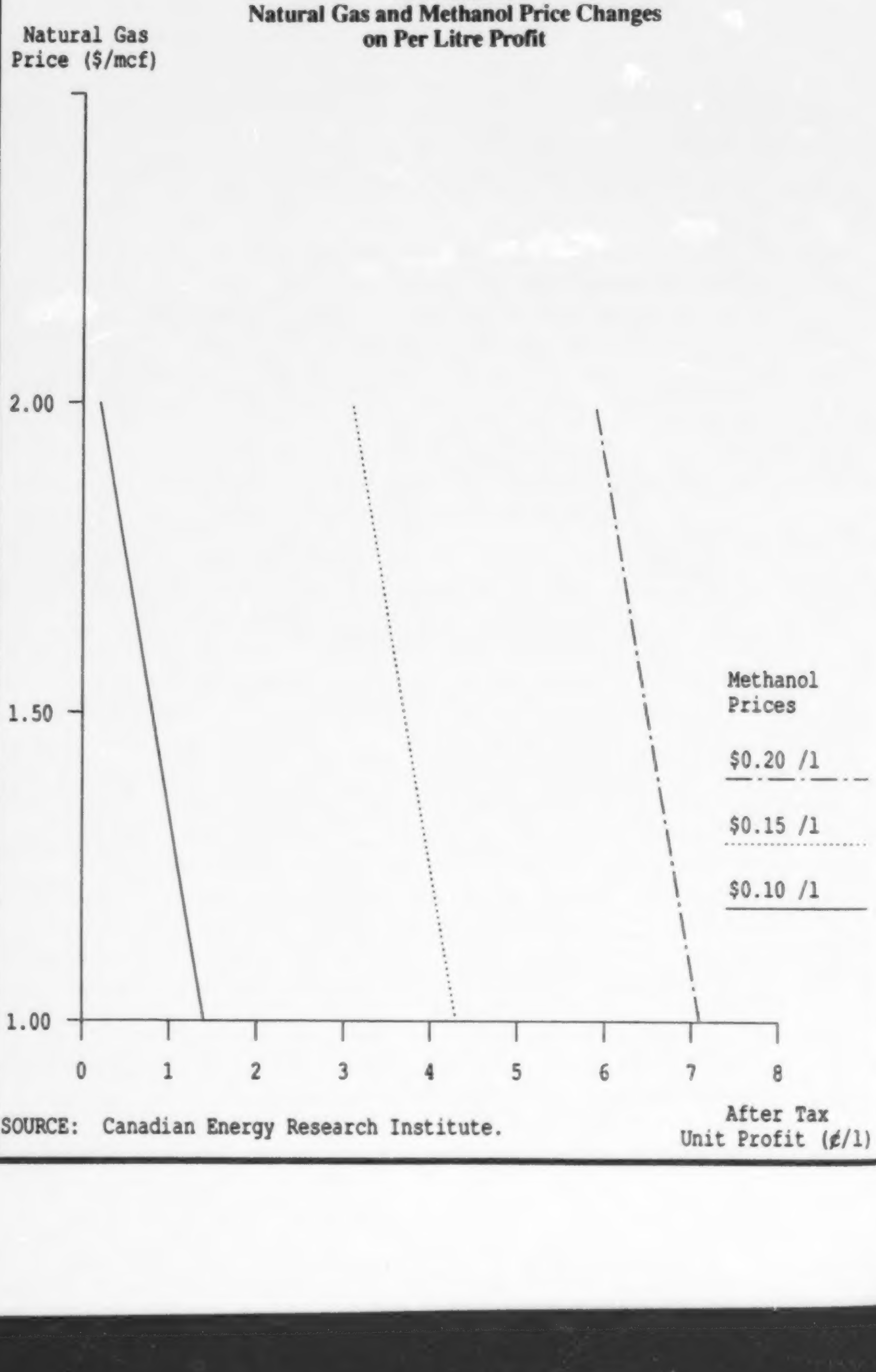
	Rate of Return (%)	Payout
Base Case Results		
Natural gas @ \$1.50/Mcf, Methanol @ 20¢/L	29.5	1991
Sensitivities on Methanol Price		
Methanol @ 10¢/L	--	--
@ 14¢/L	13.7	1993
@ 15¢/L	16.9	1993
@ 25¢/L	40.5	1991
Sensitivities on Natural Gas Price		
Natural gas @ \$1/Mcf	32.7	1991
@ \$2/Mcf	26.1	1992

SOURCE: Canadian Energy Research Institute.

NOTE: The 14 cents/litre case is included to indicate the rate of return to the base case when methanol prices are competitive with present gasoline prices.

Figure 4.10

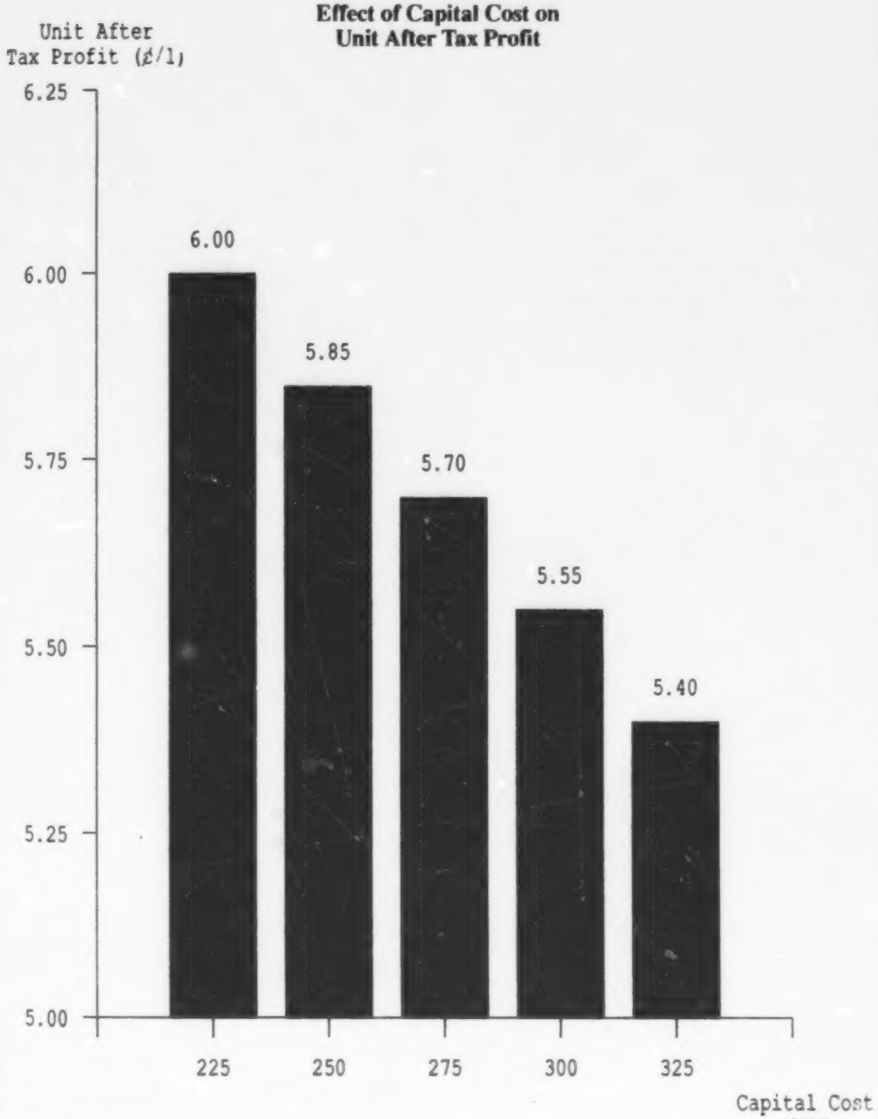
The Effect of Natural Gas and Methanol Price Changes on Per Litre Profit



SOURCE: Canadian Energy Research Institute.

Figure 4.11

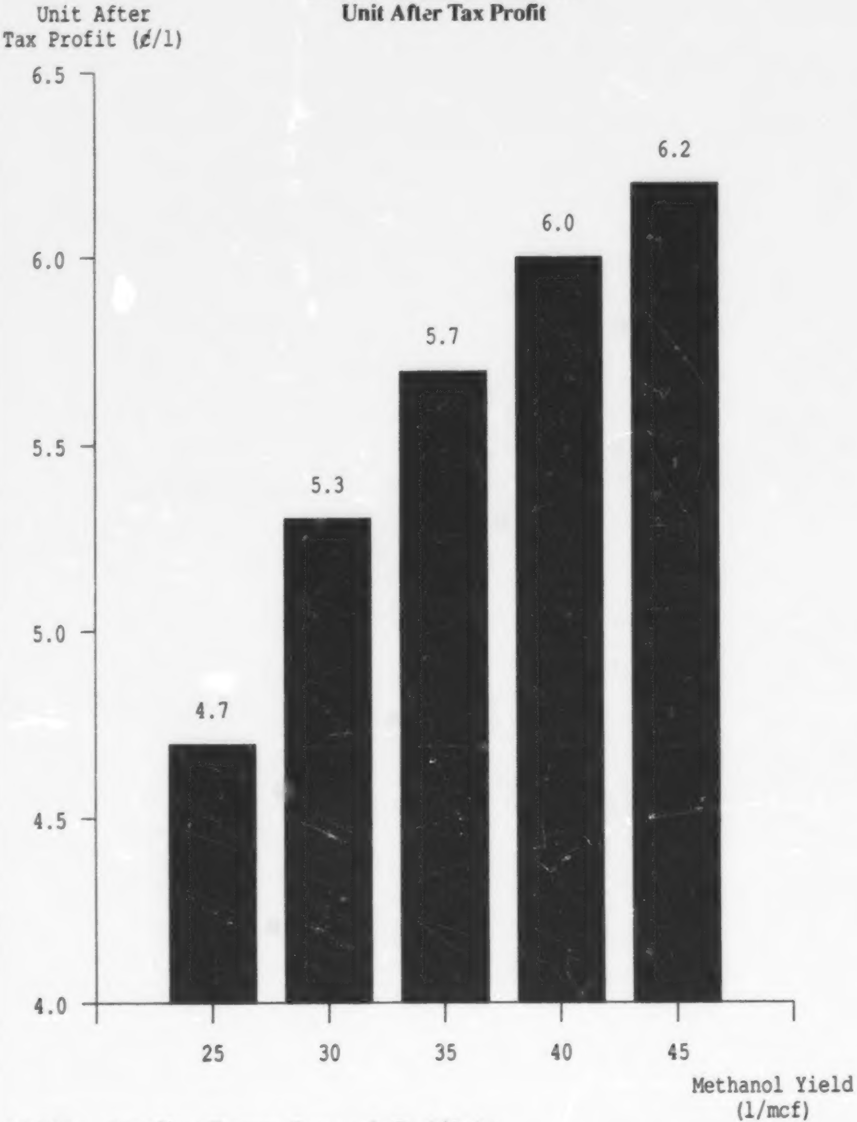
Effect of Capital Cost on Unit After Tax Profit



SOURCE: Canadian Energy Research Institute.

Figure 4.12

Effect of Methanol Yield on Unit After Tax Profit



SOURCE: Canadian Energy Research Institute.

utilization may soon play a greater role in overall demand. The analysis performed for this report suggests that methanol has the potential to compete in the transportation fuel market.

This relatively inexpensive, clean burning fuel, when used as a substitute for gasoline in dedicated or flexible fuel vehicles or when used as a replacement for diesel fuels, may not only provide the power lost through lead phase-out but may prove beneficial in meeting future air quality standards by decreasing the atmospheric NO_x and particulate levels and lowering atmospheric carbon monoxide concentrations. If California, described as the third largest consumer of petroleum products in the world, has recognized the need to establish public policies aimed at encouraging methanol consumption for energy security and air quality purposes, perhaps Canadians should take note and utilize Canadian methanol production capacity to prevent the aforementioned problem areas from reaching the proportions which they have in other countries.

Footnotes

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[5] Ibid., p. 3:34.

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[39] The Royal Society of Canada, Lead In Gasoline, Alternatives to Lead in Gasoline, The Commission on Lead in the Environment (Ottawa: February 1986), p. 31.

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Chapter 5

CONCLUSIONS

5.1 Introduction

Although petroleum-based fuels will remain Canada's principal transportation energy source in the foreseeable future, there are several good reasons for initiating a transition towards ethanol and/or methanol as alternative fuels in the immediate future:

- Uncertainties related to future sources of energy;
  - political instability in other oil producing countries,
  - declining conventional light crude oil reserves
- Unstable crude oil prices and crude price shocks;
- Environmental concerns and regulatory changes;
  - acknowledged government efforts to eliminate lead from Canadian fuels for health, safety and environmental reasons, forcing refiners to establish alternate octane sources,
  - the "greenhouse effect", ozone and carbon monoxide concerns
- The need for agricultural diversification projects due to unstable grain prices; and
- Declining diesel fuel quality.

It took over a decade for unleaded fuel use to reach 50 percent of market penetration. It would seem reasonable, therefore, to assume that even under favourable market conditions, it would take at least 5 to 10 years or longer to switch even a limited portion of this petroleum-based market over to an alternative fuel source.

According to Transport Canada, 68 percent of Canada's total petroleum consumption is absorbed by the transportation sector. Eighty percent of this is attributed to the road mode, of which two-thirds is consumed by private passenger automobiles.[1] If Canadians, in particular vehicle users, face a future in which conventional crude sources will be in short supply, and if it is true that by the year 2000 fully one-half of the world's oil will be produced in the Middle-East, an area recognized for instability and therefore, an insecure supply source, then efforts to start a transition to alternative fuel sources should be initiated in the near future.[2]

This chapter will review the rationale for determining if ethanol and/or methanol are, or can be, plausible fuel substitutes in Canada and, if so, what effects this may have on the pertinent stakeholders in the transportation energy sector.

5.2 Meeting the Requirements of an Alternative Fuel Source

There are a number of pertinent characteristics which may determine conclusively the relative opportunities for ethanol and methanol in the Canadian energy market.

- These fuels should have, or be able to attain, competitive economics within the time frame determined by Canada's declining conventional oil reserves and the need to provide octane enhancement. Though this appears currently plausible for methanol, further technological advancements will be necessary for ethanol should its use as a neat fuel be a prospect for the future.

- These fuels must be able to substitute for a current petroleum-based fuel or act as an alternative, thereby extending and eventually replacing a portion of the petroleum products being consumed in Canadian vehicles. Methanol appears to be a viable substitute for diesel fuels as well as a competitive alternative for gasoline if used in a dedicated or flexible fuel vehicle. Ethanol, on the other hand, is recognized more as an alternative fuel source which, when blended with gasoline as a gasohol product or burned as an alternative in a flexible fuel vehicle, can enhance the octane value of the base fuel as well as be useful in extending our petroleum reserves.

- These fuels must have a plentiful supply source. As Canada is rich in biomass and technological development is advancing to allow even cheaper feedstock sources from pulp, ethanol plants should not experience a supply problem. Methanol from natural gas, coal or biomass is not likely to be limited by supply constraints.

- These fuels must be easily distributable. Although alcohol fuels are not very fungible and water contamination, particularly with methanol, can lead to phase separation, tests performed in Germany, United States, New Zealand, Sweden and Canada have shown that these problems can be overcome. Sufficient technical experience has been attained to resolve any problems with distributing ethanol or methanol in blends or as fuel alcohols. Although the total expenditure involved in adapting existing distribution systems to alcohol-containing fuels may appear high, when expressed on a cost per litre basis, they appear to be more reasonable.

- These fuels must have widely developed and commercial production and vehicle technologies. Presently, ethanol produced from biomass-derived sugars is supported by fuel tax incentives. There are established technologies for both sugar and starch-based plants, some of which are undergoing further research and development to achieve improved economics and energy optimization as well as maximize the recovery of all possible by-products. Researching the use of strong acids or enzymes in the hydrolysis process used as a pre-step when converting cellulose to fermentable sugars may increase the potential for producing ethanol at much more reasonable production costs.

  In Canada, the production technology for producing methanol from natural gas is well developed and large scale production capacity is in place.

  Vehicle utilization technology is also available. Although gasohol has been found to be compatible with existing vehicles, flexible fuel vehicles as well as compression-ignition (diesel) engines have been designed to utilize alcohol fuels. However, further research and development in this area may be required to optimize the environmental benefits of these fuels.

- Alternative fuels must be environmentally acceptable. In comparison with hydrocarbon-based fuels, the exhaust emissions from vehicles burning alcohols contain negligible amounts of aromatics (benzene and polyaromatic hydrocarbons). The NO_x emissions are generally lower than from gasoline combustion. Low level alcohol blends, however, have a tendency towards increased evaporative emissions, an effect which can be offset somewhat by adjusting the volatility of the base fuel.

  The aldehyde fraction of unburned fuel, particularly for methanol, is appreciably greater than for hydrocarbon-based fuels. Although these emissions are still small in absolute terms, they can be further reduced using a catalyst. According to the U.S. Environmental Protection Agency, the most advantageous effect of methanol over gasoline is its potential to improve the levels of ozone concentrations. Air quality calculations performed using EPA's EKMA-II model showed that converting 100 percent of light duty vehicles to M85 in a number of cities outside California would reduce the ozone concentration from 4 to 14 percent. In the South Coast Air Basin in California, 100 percent use of methanol could reduce peak ozone levels from 14 to 18 percent.[3]

  > Taking all facts known into consideration, fuel alcohols do not appear to entail more detrimental

> effects to the human health and environment than gasoline and diesel-oil. On the contrary, in some respects the use of alcohol could bring about an improvement.[4]

- Alternative fuel sources must provide social benefits in the form of job creation and regional development. Although the ethanol fuel industry may not provide the job creation, regional development and industrial diversification that developing frontier oil reserves, heavy oil through upgrading or the tar sands may provide, it does have the potential to provide economic stability for farming communities on the edge of economic collapse. Minnedosa, Manitoba may not have been on the map today if the Manitoba government had not recognized the ability of an ethanol plant to bolster the economy of this economically troubled community. The Mohawk ethanol plant provides local area farmers with assured markets for their grain and stimulates job creation throughout the community.

  Future regional diversification projects of this type would probably be tied into a feedlot and although neither the ethanol industry nor the feedlot industry currently appear economically viable on a stand-alone basis, recent studies undertaken in Saskatchewan[5] suggest that combining these two industries can result in a viable business undertaking.

  It must be pointed out that the economics developed in this study were based on grass root plants only. The analysis performed indicates that government support would be a necessity to place ethanol on a competitive level with other fuel sources. Fuel tax exemptions will not be adequate to support the 10 million litre per year agricultural diversification projects, let alone that of a large commercial scale project. In other words, if ethanol is to be produced as a fuel source, government grants and/or subsidies will be required, at least in the short term.

- Although the methanol industry is well developed in the petrochemical industry, further expansion into the automotive fuel sector would also lead to the creation of additional employment opportunities.

5.3 Reflections on the "Stakeholders": Their Role, Risks and/or Opportunities

5.3.1 The Alcohol Producer

The alcohol producer, in attempting to increase the alcohol share of the fuel market, must be the major risk taker. The producer must be willing to expand production in advance of demand and in anticipation of increased market penetration levels, as the availability of alcohol-compatible vehicles and a surplus of supply of either ethanol or methanol will encourage market opportunities should oil prices rise, a petroleum supply upset occur or octane enhancement gain in demand. Inadequate development of production facilities could result in the fear of supply shortages and prevent consumers from purchasing vehicles designed for alcohol fuels.

However, being the risk taker and expanding capacity is often deleterious to the economics of an industry. Alberta Gas Chemicals, Celanese and Ocelot witnessed this in the late 1970s and early 1980s when they invested close to a billion dollars in the expansion of methanol production facilities in Canada, only to be faced with a drop in world oil prices and a world surplus of methanol due to increased capacity in areas of low cost natural gas.

The ethanol and methanol producers will at least need assurance of markets for their products, if they are to take the risks involved with expanding into the energy market.

5.3.2 The Agricultural Industry

To suggest that all Canadian farmers will benefit equitably from an ethanol industry would be unrealistic. A study undertaken by Agriculture Canada in 1987 to determine the potential market impact of increased feed grain demand due to ethanol production suggests that, using long-run elasticities of demand to simulate market adjustment and assuming corn countervail is not in effect, grain prices could increase by as much as 2 percent in the West and 6 percent in the East.

The study also suggests that savings to the government from decreased payments due to the Western Grain Stabilization Act (WGSA), Agricultural Stabilization Act and the Western Grain Transportation Act could total almost $31 million. It is recognized, however, that the nature of the WGSA program suggests that with increased grain prices, payments initially will start to go down. However, because funds are paid out based on the difference between the current year's aggregate net income compared to the previous 5 years average, should grain prices later become depressed, eligibility payments could increase.

Regionally, however, farmers can prosper from an ethanol industry as noted in the case of Minnedosa, Manitoba where Mohawk converted an old distillery into an ethanol plant and the farmers in this previously economically declining area gained assured markets for their grain.

A similar scenario is planned for Weyburn, Saskatchewan. With help from the federal government's Western Diversification Fund, Heathern

Distilleries will reopen a shut-down Weyburn distillery to produce ethanol. Alongside this plant, a sister company will process liquid stillage into both wet and dry feedstock products. The ethanol plant, expected to be at full production by April 1989, will produce 7.5 million litres of ethanol annually. This joint agricultural diversification project will benefit neighbouring farmers by providing a secure market for their grain, as well as create jobs which will bolster the economy of the town itself.

5.3.3 The Refiner, Marketer and Distributor

As lead phasedown occurs, Canadian oil refiners will select the octane source which they feel is most suitable to their situation. After all, in considering alcohol blends, it is the refiners who must ultimately satisfy their customers if they are to remain successful in the highly competitive marketplace. To maintain product integrity, they must be able to produce a quality fuel which satisfies the customers' real or perceived performance requirements. The majority of the large integrated refiners have suggested that isomerization and/or higher severity reforming can and will supply their octane requirements; however, some of the smaller independents may find alcohol fuels the more economical means of attaining their needs.

Ignoring the positive environmental aspects associated with neat or near neat fuels and considering only alcohol use as an octane enhancer for gasoline blends, there are two issues which require further examination:

(i) Oxygenates Versus Additional Refinery Processing

According to a paper published in 1986 by the Royal Society of Canada discussing lead in gasoline, increasing the octane value of gasoline by more severe reforming tends to increase the concentration of the aromatic hydrocarbons in the final product. The report noted that, "Alcohol blends present an attractive health and environmental alternative to the increase of aromatic hydrocarbons resulting from severe reforming."[6]

The Royal Society's paper suggests that a more attractive option to higher reforming would be isomerization, as the exhaust emissions attributable to this process would be simply those of gasoline. Therefore, "the health implications would be not greater than at present for efficiently functioning catalyst-equipped cars."[7] Though the capital costs attributed to an isomerization plant are high, on a per litre basis to the consumer they would be relatively small.

(ii) Alcohols Versus Methyl Tertiary Butyl Ether (MTBE)

Though MTBE will not "substitute" for a fuel in the energy market, as might methanol and/or ethanol, it is recognized as an excellent octane enhancer which is totally miscible with gasoline and immiscible in water.

Gasoline blended with 10 to 11 percent MTBE tends to act like a normal hydrocarbon-based fuel which is about one octane rating higher. Engine studies have indicated that power output and energy efficiency are about equivalent to that of gasoline fuels. Exhaust emission tests indicate that CO decreases, NO_x increases and hydrocarbon emissions remain essentially unchanged. The toxicological aspects of MTBE from inhalation, ingestion, or skin absorption have been found to be, " ... no worse than gasoline."[8] It is also important to note that MTBE is relatively unreactive in the atmosphere and therefore is not inclined to contribute to ozone formation. Although MTBE would most likely prove to be the refiners' choice of oxygenate as an octane-enhancer, availability of isobutylene may pose a problem in the future.

Development of an oxygenated fuels program would also initiate a number of concerns for pipelines. Substantial capital expenditures may be involved. Facility expansion and adjustments in operational procedures would be required if there were significant increases in alcohol fuel transportation volumes. Other concerns involve adequate breakout or in-transit tankage, scheduling adjustments and commingling of MTBE and non-MTBE or clear gasolines (assuming MTBE fuels are blended at the refineries and ethanol and methanol blending is accomplished at the terminals). Pipelines operating common carrier terminals would also have to consider loading rack facilities and adequate terminal storage.

As long as oil prices remain low, it is unlikely that oxygenates as octane enhancers will receive much support from the refiner unless environmental concerns result in either mandated use of these fuels or economic incentives large enough to counteract the costs and risks involved in large scale alcohol fuels use.

5.3.4 The Automobile Manufacturer

The automobile manufacturer may well be the "stakeholder" that ultimately determines the value of alcohol fuels to Canadians. These participants have made massive investments in the manufacture of traditional gasoline consuming vehicles. Manufacturing alternative and flexible fuel vehicles will involve the additional risks associated with retooling costs, as well as the marketing costs necessary to ensure sufficient sales to justify production costs. It is in acknowledging this fact that refiners have stated that unless motor vehicle manufacturers publicly support a fuel blend, they are not interested in marketing it.

Appropriately designed alcohol-fuelled vehicles can be efficient, high performance machines. The vehicle technology for either fuel ethanol or fuel methanol is essentially the same. In fact, one vehicle model (the flexible fuel vehicle) could serve for either fuel simply by making minor fuel metering adjustments. The future use of alcohols as alternative transportation fuels in Canada is at a critical decision point and the commercialization of the flexible fuel vehicle could circumvent the "chicken-or-egg" problem that may otherwise obstruct the introduction of these fuels into the market. However, it is unlikely that retail buyers will be induced to purchase flexible fuel vehicles unless either the fuel or the vehicle is sold at below cost ... another risk for this stakeholder.

5.3.5 The Canadian Consumer, The Canadian Citizen

All the start-up risks associated with introducing ethanol and methanol as octane enhancers or fuel substitutes ultimately reside with the Canadian consumer. The marketing efforts of the alcohol producer, the oil refiner and the automobile manufacturer are directed towards consumer satisfaction. Good vehicle performance is the primary requirement of a fuel by all the stakeholders, but particularly from the viewpoint of the end-user.

The initial costs of introducing an alternative fuel are high. The Canadian consumer would ultimately pay the cost for the gasoline extender, the octane enhancer and/or the fuel substitute. But, the Canadian citizen would also be the primary beneficiary of heightened energy security and a cleaner environment.

5.3.6 The Government

The risks are high for all of the stakeholders involved in introducing alcohol fuels to the marketplace. Utilizing alcohol, particularly ethanol, would require the close association of agricultural systems, alcohol plants and assured markets in the energy sector for the refiner. Reliable raw material supplies and an alcohol distribution network will be necessary. The vehicle-first versus the fuel-first issue must be resolved. The consumer will have to be made aware of the new fuels, their advantages and their disadvantages. Direction will be required.

Prior to lead phasedown or the introduction of a "Clean Air Act" for Canada, the role of alcohol fuels will be determined by government action. Governments will need to be the director in this commercial experiment, the arbitrator, to accommodate the conflicting needs of the various sectors of the economy involved.

The governments (federal and provincial) must develop a long-term perspective as market forces, particularly in the energy sector, tend to respond strongly to short-term requirements while discounting long-term costs or benefits. Current involvement in the transportation sector by both levels of government as end users, tax collectors, and investors in research, development and demonstration, already defines their "role" as the arbitrator who must regulate fuel and fuel-using equipment qualifications as well as product distribution and dispensing. Should economic incentives be necessary, they must be in a form which will assure a fair share for all the risk takers.

5.4 Regional Perspectives

5.4.1 British Columbia

B.C. refineries, in general, are less proficient than other Canadian refineries at manufacturing high-octane gasoline components.[9] For this reason, with lead phasedown, oil companies confronted with either major capital investments or shutdown may welcome the development of an alcohol fuel industry as an opportune investment to provide a source for their octane requirements.

British Columbia is rich in forest reserves and contains over 25 percent of Canada's pulp industry, which generates massive amounts of wood waste. Should acid hydrolysis or enzyme treatment conversion techniques for turning wood into ethanol become economical, site specific plants could prove quite profitable to B.C. refineries. Location, however, would be a determining factor as to the profitability of the project, as a major part of the cost is in harvesting and transporting the wood-based feedstock to the processing plant.

Utilizing methanol in the fuel industry would provide economic security for Ocelot, B.C.'s world-scale methanol producer which, until recently, was competing under a world surplus scenario and could be confronted with the same again in the near future.

5.4.2 Alberta

Most of Alberta's refineries have started up over the past 20 years (an exception being Parkland's Bowden refinery) and technically should be capable of meeting current octane requirements. However, the 1990 gasoline specifications may leave them octane short, thus requiring either new equipment and/or facilities or octane enhancers. (Also of note is that future oxygenate demand may be even greater if Alberta refineries are adapted to handle more bitumen and heavy oils.)

The alcohol industry could potentially provide a portion of these octane requirements while at the same time providing agricultural diversification projects for Alberta's farmers who until this years drought have been confronted with depressed grain prices. As Alberta has vast grain fields plus a tremendous beef industry, an ethanol industry has the potential to provide the agricultural regions in the vicinity of the ethanol plant with assured markets for their grains while at the same time supplying the beef producers in the area with the high energy protein animal feed by-products.

However, a recent study performed by the Alberta Grain Commission determined that, "the minimum cost to the public treasury is greater than the maximum benefit to agriculture, and evidence does not exist to demonstrate that fuel ethanol would provide a net positive economic benefit for Alberta."[10] The Commission's determination that for fuel ethanol to be cost competitive with gasoline, long-term financial support will be a necessity is strongly supported by the economic analysis contained in this report. The question of overall, net social cost or benefit from support for an ethanol industry is, however, still open to debate.

Another major consideration regarding alcohol fuels for this province is the fact that under the current low oil price regime, some of Alberta's refiners have expressed the concern that an ethanol industry would reduce the markets for the products they are currently producing for the transportation industry. As Alberta's economy is largely supported by the petroleum industry, this concern must be given serious consideration.

Alberta's methanol producers (Alberta Gas Chemicals and Celanese), until recently faced with a world surplus for their product, would welcome new markets in the transportation sector to alleviate any concerns regarding the need for secure markets for their product.

5.4.3 Saskatchewan

On October 15, 1987, the Government of Saskatchewan published a news release which stipulated a major ethanol incentive program designed to "create a significant new market for Saskatchewan grains."[11] Recognizing the potential of an ethanol industry in providing a means of diversification for new grain markets, Premier Grant Devine established a graduated scale incentive program based on the amount of ethanol in the blend, outlined in Section 3.6.5. To qualify for the program, the ethanol used to produce the blend must be "produced in Saskatchewan solely using Saskatchewan grown grain."[12] The recent federal government support granted to the joint ethanol and feed product operation scheduled for Weyburn suggests this incentive may well have provided the spark necessary to promote an ethanol industry in Saskatchewan. It is definitely a catalyst for diversification and a progressive move towards initiating further studies into the advantages of this fuel for "grain rich" Saskatchewan.

5.4.4 Manitoba

The gasohol market has proven to be a progressive establishment for Manitobans. Provincial support for gasohol influenced Mohawk's decision to establish an ethanol industry in Minnedosa and to market ethanol gasoline blends. Significant town and community support have also helped maintain the alcohol industry, which has in turn helped to sustain a town and farming community whose livelihoods were jeopardized when the distillery that Mohawk has since converted into an ethanol plant was shut down in 1972. An assured grain market was developed for the farmers in proximity to the plant and the Manitoba meat packing and feedlot industry has been enhanced as a result of the high value protein feed supplement made available as a by-product from the alcohol production.

As noted earlier, the Manitoba government, in cooperation with Energy, Mines and Resources Canada, has researched the potential for gasohol in current vehicles in order to assure themselves and the Manitoba fuel consumer that this ethanol blend is indeed an efficient fuel. This was established in the findings which evolved from the Gasohol Fleet Test, finalized in March of 1983.

5.4.5 Ontario

Ontario has for some years encouraged greater participation in the use of alternative fuels. The Ontario Ministry of Energy has participated with industry to advance the knowledge in production and use of alcohol fuels. It has funded industry research on the conversion of cellulosic feedstocks into ethanol. It has also co-funded vehicle demonstrations on different oxygenated fuels and made public the results of its findings.

As Ontario motorists will consume over 12 billion litres[13] of gasoline in 1988, the Province has a vested interest in developing alternative energy sources capable of reducing provincial dependence on petroleum-based transportation fuels. Ontario has great potential for ethanol produced from either corn or wood, as there is an abundance of both in this province. Also, although it currently is cheaper to produce methanol from natural gas in Canada, there is future opportunity in methanol production from Ontario's Onakawana lignite deposit.[14]

5.4.6 Quebec

Quebec is totally dependent on off-shore supplies and crude oil from Western Canada to supply its transportation energy needs and, therefore, is particularly vulnerable to shocks in the world oil market. The Province imports the equivalent of 25,000 barrels per day of gasoline from outside of Canada.[15] As Quebec maintains a considerable reserve of marginal agricultural lands and is rich in abundant forest wastes and low quality timber, there is potential to alleviate some of its energy requirements with a fuel ethanol industry.

A great deal of the expertise regarding the alcohol industry has been developed in Quebec. Commercial Alcohols of Montreal is Canada's largest producer of industrial ethanol from ethylene feedstock. Until 1986, BASF produced isobutanol in Montreal. IBA was blended with methanol and gasoline and sold at V-Plus, Pioneer, and Domo stations.

The potential for producing ethanol from wood has also been the focus of a great deal of research in Quebec. The Techtrol/Iotech Group have invested many years of research in the development of the cellulose enzyme technology necessary to make this conversion process economically viable. Achieving this goal could make ethanol competitive as an alternative fuel for Canadians if markets are assured for the lignin by-product.

The Department of Agricultural Economics at MacDonald College has investigated both the potential of ethanol as a gasoline extender and as an octane enhancer. Their research has focussed on the feasibility of using Jerusalem artichokes grown on marginal lands as the feedstock to produce ethanol. Their tentative results indicate that ethanol can be produced from this crop for as low as 33 cents per litre, assuming the ethanol is being produced in a 100 million litre per year plant.[16]

Producing methanol from the abundant supplies of wood available in Quebec may also have potential long-term prospects. Studies focussed on using forests and municipal wastes in the production of methanol are being conducted at the Biosyn plant in Southern Quebec.[17]

Quebec has a great deal of expertise and potential for an alcohol fuel industry. However, there is no tax exemption for alcohol fuels currently available in this Province, nor special fiscal incentives for companies who might consider entering the market. As a result, investors are leery to make a commitment. It appears that government support will be required if the alcohol fuel industry is to take hold in Quebec in a significant way.

5.4.7 Atlantic Canada

Short-term prospects for a commercial-scale ethanol industry in the Atlantic Provinces do not appear positive. There is potential, however, for benefits to regional niches where food wastes, potato culls or wood wastes might be used in a fuel alcohol industry for local use. Note also that offshore natural gas could make methanol production in Nova Scotia a long-term prospect. For these reasons, the Atlantic Provinces are not adverse to positive stimulation of the alcohol fuel industry in Canada through more research and development efforts.

5.4.8 The Yukon and the Northwest Territories

Though officials in the Yukon and the Northwest Territories do not feel ethanol or methanol are fuels currently applicable to their markets, they believe the research and development being applied across Canada regarding these alcohols is beneficial, especially concerning the environmental effects of cleaner burning fuels.

5.5 National Perspectives

Lower oil prices have once again masked the need for Canadians to have alternative fuel sources available to turn to when price shocks push oil and product prices to high levels. These uncertain parameters in the market environment make private sector investment in the development of new energy sources, such as ethanol, appear uneconomical in the short term. However, the long-term benefits of octane enhancement, fuel security and cleaner air should be given serious consideration. A direction must be determined to assure Canadians of efficient, clean burning fuel supplies. The governments can help by providing leadership, information and supporting relevant research.

As the arbitrators who set fuel-using equipment standards and regulate product distribution and dispensing, the potential for alternative transportation fuels largely depends on what the various Canadian government bodies deem that potential to be. If these energy sources are to be given serious consideration as alternative transportation fuels, an infrastructure for the production, marketing and distribution of these fuels must be developed. High initial costs must be reduced and, very importantly, consumers must be convinced of the benefits that may be attained from the use of alternative fuels.

In order to develop alternative fuel sources for the Canadian transportation sector, efforts need to be accelerated to encourage their development. Otherwise, their long-term potential may never materialize.

5.6 Commercializing Alcohol Fuels

The merits of ethanol and methanol as blending agents or fuel substitutes in Canada cannot be fully determined without advancing to the commercial level. To ascertain harmony between all the players affected by this immense undertaking will require:

- Appropriate legislation and support to:
  - ensure fuel system integrity,
  - develop safety standards regarding flash points, flammability limits and ignition temperatures,
  - ensure labelling and/or denaturing of the product to prevent such mishaps as the ingestion of methanol mistaken for potable ethyl alcohol,
  - enforce the use of proper blending techniques ("splash blending" would be discontinued),
  - promote improved air quality by regulating pollutants contained in exhaust and evaporative emissions from cars, and
  - standardize handling and distribution for safety reasons, as well as to maintain product quality in "swapping" agreements
- Continued efforts to develop cost-effective technology to lower production costs and ultimately the selling price, particularly in the case of ethanol; and
- Education of the Canadian citizen as to the economic, technical and environmental advantages and disadvantages associated with the introduction of alcohol fuels.

5.7 Recommendations Leading to the Commercialization of Alcohol Fuels

This study has provided a review of the potential of ethanol and methanol as alternative transportation fuels in Canada. The ethanol section was more extensively developed as the infrastructure for methanol production in Canada has been in place and well defined for many years. The research and analysis performed for this report suggest that currently neat methanol has the potential to effectively compete in the transportation fuel market, whereas ethanol has not yet been proven to be economically viable. On the basis of the research underlying the study and results of the economic analysis performed, the following recommendations are put forth:

Recommendation 1. If ethanol and/or methanol are to become viable alternative fuel sources in Canada, assurance of both federal and provincial commitment will be necessary for all the stakeholders involved. These government bodies will need to work together to determine a long-term perspective as market forces, particularly in the energy sector, tend to respond strongly to short-term requirements while discounting long-term costs or benefits.

Recommendation 2. More extensive investments will be necessary in terms of research, development and demonstration if alcohol fuels are to be introduced to Canada on a national basis.

Recommendation 3. If these energy sources are to be given serious consideration as alternative transportation fuels, the infrastructure for the production, marketing and distribution of these fuels must be developed.

Recommendation 4. Though the regulation of gasoline quality is a provincial obligation, not all of the provinces have formal specifications for gasoline or similar type fuels. Commercialization of alcohol fuels will require a common set of rules and regulations across Canada which would ensure competitive equity among the players involved.

Recommendation 5. Where economic incentives are determined to be desirable, they must take a form which will assure a fair share for each of the risk takers involved in an alcohol fuel project.

Recommendation 6. A commercial-size fuel ethanol plant could determine for Canadians the potential of this alcohol as an environmentally safe, nationally acceptable fuel source. If an ethanol project is joint-ventured with an oil refinery and a feedlot for a specified time period, and if enough capital is invested to assure each participant a fair rate of return during the experimental stages, methods may be determined to lower production costs as well as to solve many of the existing problems associated with an ethanol industry. If, however, the real value of a fuel ethanol industry to Canadians stems from its ability to provide the regional diversification projects necessary for economic stability in a number of rural communities across Canada, then each project will require federal and provincial consideration on a regional basis with the allocation of funds determined according to the individual merits of the project.

Recommendation 7. Further studies need to be undertaken to determine the environmental pros and cons related to ethanol and methanol fuels. Studies similar to those being researched in California regarding the benefits of using methanol for reducing ozone levels, and in Colorado to reduce carbon monoxide levels, should be undertaken in Canada and the results made known to the public.

Recommendation 8. If further research regarding a number of environmental concerns indicate that oxygenated fuels may prove beneficial in lowering carbon monoxide and particulate levels in Canada, mandating oxygenated fuel use by the public at least over the winter months should be considered. This would alleviate inconsistencies encountered by the refiner/marketer/distributor who must cross provincial borders.

Recommendation 9. Ethanol and methanol prices will need to be stable and competitive relative to gasoline and diesel fuel if these fuels are to gain wider market shares through expansion into the fuel industry.

The Canadian energy sector plays an extremely important role in our economy. It is with this understanding that Canadians must consider all sources of fuels available to our society and the potential long-term economic, social and environmental effects. In recognizing this, Canadians may need to progress from the experimental to the commercial stage in order to ascertain the long-term value of ethanol and methanol to the Canadian transportation sector.

Footnotes

[1] Transport Canada, Energy Research and Development Strategy, 1988/89 and Beyond (Ottawa: Research and Development, October 1987), p. 8.

[2] Harold L. Walters, Ford Motor Co., Necessary Incentives for a Methanol Fuel Market, SAE Technical Paper Series 861572, Philadelphia, Pennsylvania, October 6-9, 1986, p. 5.

[3] International Energy Agency, Alcohols and alcohol blends as motor fuels, prepared by the Swedish Motor Fuel Technology Co., Vol. II B. (Sweden: October, 1986), p. 9:33.

[4] St. Lawrence Starch Limited, Phase I: Pre-feasibility Study for a Comprehensive Alcohols Study for the Province of Alberta, prepared for Alberta Agricultural Processing Development Branch, Alberta Agricultural Marketing Services Division, November 1986, p. 27.

[5] Shafer, Del, The Integration of Ethanol Production with Cattle Feeding, paper presented to the Canadian Power Alcohol Conference, Winnipeg, Manitoba, October 3, 1988.

[6] The Royal Society of Canada, Lead in Gasoline, Alternatives to Lead In Gasoline, prepared by the Commission on Lead in the Environment (Ottawa: February, 1986), p. 26.

[7] Ibid., p. 4.

[8] The Royal Society of Canada, Lead in Gasoline, Alternatives to Lead In Gasoline, prepared by the Commission on Lead in the Environment (Ottawa: February, 1986), p. 22.

[9] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, Cat. no. M92-19/1986E (Ottawa: Supply and Services, 1986), p. 77.

[10] Ken Beswick, Alberta Studies and Policy Development. This presentation to the Canadian Power Alcohol Conference summarized the findings of the report entitled An Assessment of the Costs and Benefits of an Ethanol Industry in Alberta, published May 11, 1988 by the Alberta Grain Commission, Winnipeg, Manitoba, October 3, 1988.

[11] Government of Saskatchewan, Incentives Announced for Ethanol Industry, News Release published October 15, 1987.

[12] Saskatchewan, Department of Agriculture, The Ethanol Production and Marketing Incentive Regulations (Regina: Department of Agriculture, Oct. 16, 1987.)

[13] Barry Beale, Oxygenated Fuels In Ontario, paper presented to the Canadian Power Alcohol Conference, Alcohol Fuels for Transportation, Winnipeg, Manitoba, October 3, 1988, p. 1.

[14] Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, 1986 Summary, Cat. no. M92-19/1986E (Ottawa, Supply and Services, 1986), p. 79.

[15] J. C. Henning, L. B. B. Baker, P. J. Thomassin, and L. A. Fischer, Department of Agricultural Economics, MacDonald College of McGill University, Montreal, Quebec. Fuels Ethanol Policy and Developments in Quebec. Presentation by L. B. B. Baker to the Canadian Power Alcohol Conference, Alcohol Fuels for Transportation, Winnipeg, Manitoba, October 3, 1988, p. 2.

[16] Ibid., p. 14.

[17] Ibid., p. 11.

APPENDIX A

CHARACTERISTICS OF ETHANOL AND METHANOL

PHYSICAL PROPERTIES OF ETHANOL, METHANOL, GASOLINE AND DIESEL FUEL

	Unleaded Gasoline Mixture of Hydrocarbons (mainly C_4-C_{10})	Ethanol (C_2H_5OH)	Methanol (CH_3OH)	Diesel Fuel No.2 Mixture of Hydrocarbons (mainly C_{12}-C_{20})
Boiling Range (°C @ 1 kg/cm^2)	27-216	78	65	160-382
Density (kg/m^3)	69-78	78.7	78.7	78-88
Energy Content Btu/kg Btu/L	 41,200-42,100 247,000-267,000	 25,400 167,000	 19,000 125,000	 41,700 271,000-282,000
Autoignition Temp. (°C)	232-482	424	464-470	204-260
Flashpoint (°C)	-43	21	11	52
Octane Number Range (R + M)/2	87 to 93	100	99	N/A
Flammability Limits (vol.% in air)	L=1.4 H=7.6	L=4.3 H=19.0	L=6.7 H=36.0	L=0.7 H=5.0
Sulphur Content (% wt.)	0.020-0.045	None	None	0.20-0.25
Flame Speed (cm/sec.)	40	40	40	40

SOURCE: (1) Bio-joule, September 1988 and (2) Canadian Energy Research Institute.

LEGEND: L = lower, H = higher.

TABLE A.2

EFFECT OF OXYGENATED FUELS ON REFINERIES GASOLINE BLENDING PROPERTIES OF OXYGENATES AND OTHER COMPONENTS

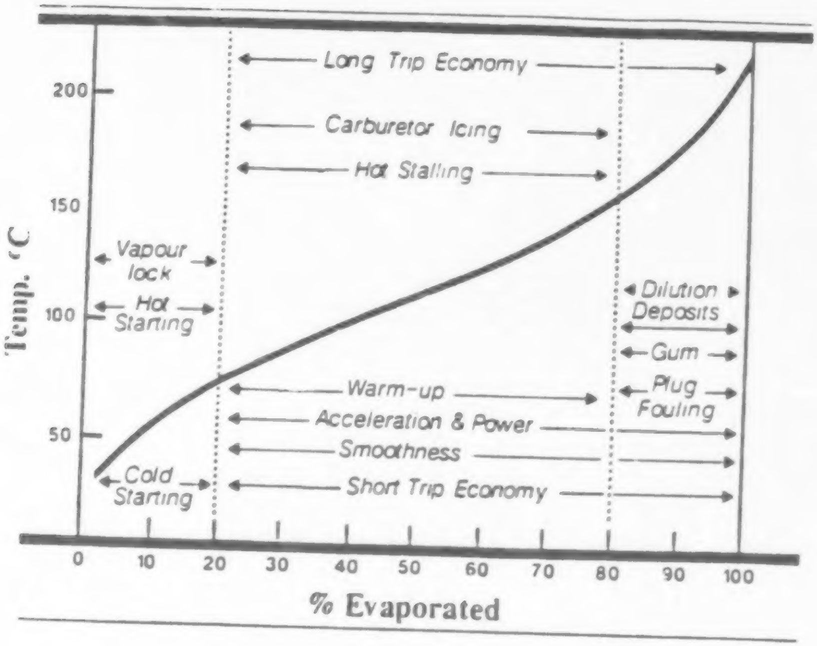
Oxygenates	Octane									Volatility		
	Unleaded Regular			Unleaded Premium			Leaded Regular			RVP,	% Off	
	RON	MON	(R+M)/2	RON	MON	(R+M)/2	RON	MON	(R+M)/2	psia	at 70°C	at 100°C
Ethanol (10%)	134.0	102.0	118.0	135.5	103.5	119.5	135.3	103.2	119.3	20	148	105
Methanol/Ethanol (5%/3%)	125.0	99.0	112.0	126.5	100.5	113.5	126.3	100.2	113.3	37	150	85
Methanol/IPA (4.75%/4.75%)	125.5	98.5	112.0							26	130	95
(7%/3%)	127.5	99.5	113.5							28	135	90
Methanol/IBA (4.75%/4.75%)	122.0	95.0	108.5							27	120	105
(7%/3%)	125.5	96.5	111.0							33	125	100
Methanol/TBA (4.75%/4.75%)	119.0	97.0	108.0	122.0	100.0	111.0	122.9	101.3	112.1	33	120	105
(5%/3%)	121.5	97.5	109.5	124.5	100.5	112.5	125.1	101.2	113.2	42	125	100
(7%/3%)	123.0	98.0	110.5							35	125	100
MTBE (11%)	119.0	97.0	108.0	121.5	99.5	110.5	122.1	99.9	111.0	9	60	110
Toluene	115.0	97.0	106.0							1	0	0
Normal Butane	94.5	89.5	92.0							60	115	100

Note: (1) Lead content = 0.027 g/L.

SOURCE: Energy, Mines and Resources Canada, Optimized Linear Program Analysis of the Effect of Oxygenated Fuels in Canadian Refineries, prepared by Hycarb Engineering Ltd., Report no. TE\-86-5 (Ottawa: Ministry of Supply and Services, March 1986), Table 5.

Figure A.1

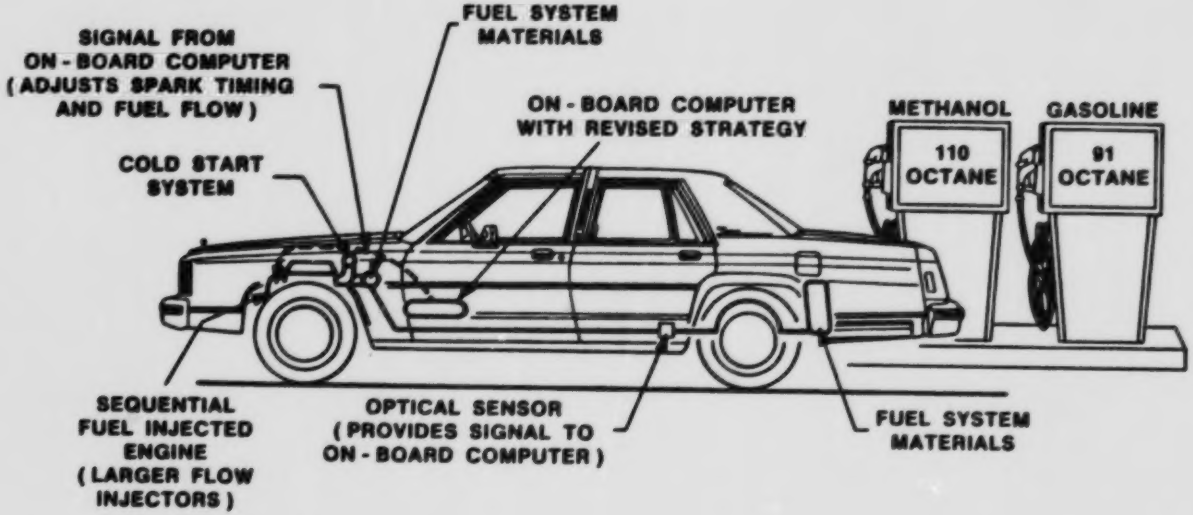
Effects of Volatility on Engine Performance



SOURCE: Energy, Mines and Resources Canada, Discussion Paper on Oxygenated Gasolines, Cat. no. M92-19/1986E (Ottawa: Ministry of Supply and Services, 1986), p. 19.

Figure A.2

1986 Ford Crown Victoria FFV Test Vehicle
(major unique flexible fuel vehicle components)


SIGNAL FROM ON - BOARD COMPUTER (ADJUSTS SPARK TIMING AND FUEL FLOW)
COLD START SYSTEM
FUEL SYSTEM MATERIALS
ON - BOARD COMPUTER WITH REVISED STRATEGY
METHANOL
110 OCTANE
GASOLINE
91 OCTANE
SEQUENTIAL FUEL INJECTED ENGINE (LARGER FLOW INJECTORS)
OPTICAL SENSOR (PROVIDES SIGNAL TO ON - BOARD COMPUTER)
FUEL SYSTEM MATERIALS

Regular production 1986 Ford LTD Crown Victoria sedans were specially modified at the Ford Scientific Research Laboratories in Dearborn, Michigan to run on methanol or gasoline, or any combination of the two. The major unique components of the Flexible Fuel Vehicles system are shown in this schematic drawing. The heart of the system is an optical sensor that measures the percentage of methanol in the fuel and signals the computerized engine controller to continually adjust the engine operating strategy for optimum performance. Ford Motor Company has conducted research for 20 years to assure that there are alternatives to petroleum-fuelled vehicles in the future.

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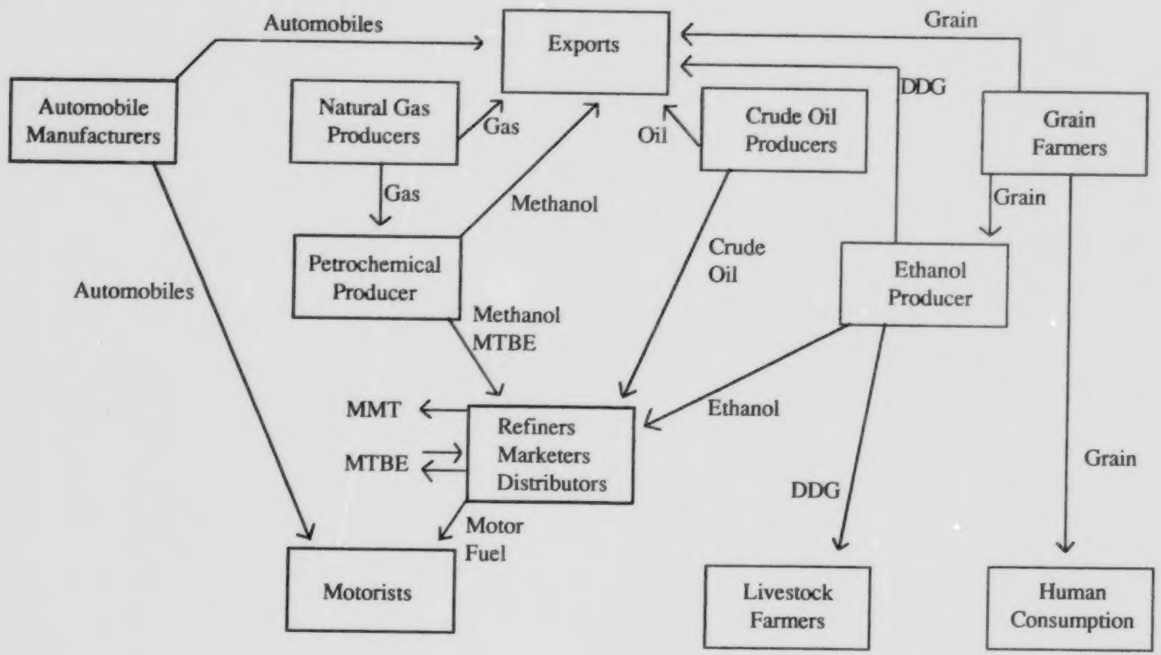
Figure A.3

Ethanol and Methanol Market Relationships


Automobiles
Exports
Grain
DDG
Automobile Manufacturers
Natural Gas Producers
Gas
Oil
Crude Oil Producers
Grain Farmers
Gas
Methanol
Grain
Crude Oil
Petrochemical Producer
Ethanol Producer
Automobiles
Methanol MTBE
MMT
Refiners Marketers Distributors
Ethanol
MTBE
Grain
DDG
Motor Fuel
Motorists
Livestock Farmers
Human Consumption

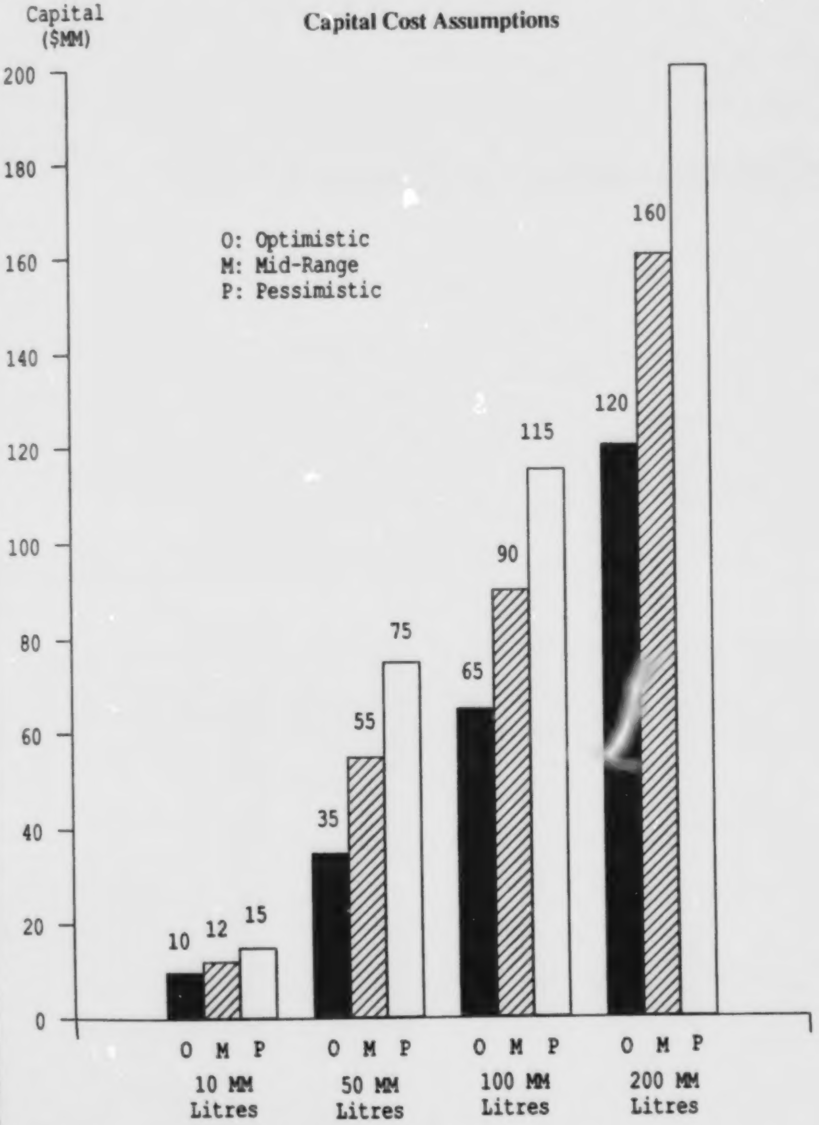
SOURCE: Canadian Energy Research Institute.

APPENDIX B

ETHANOL BASE CASES

Figure B.1

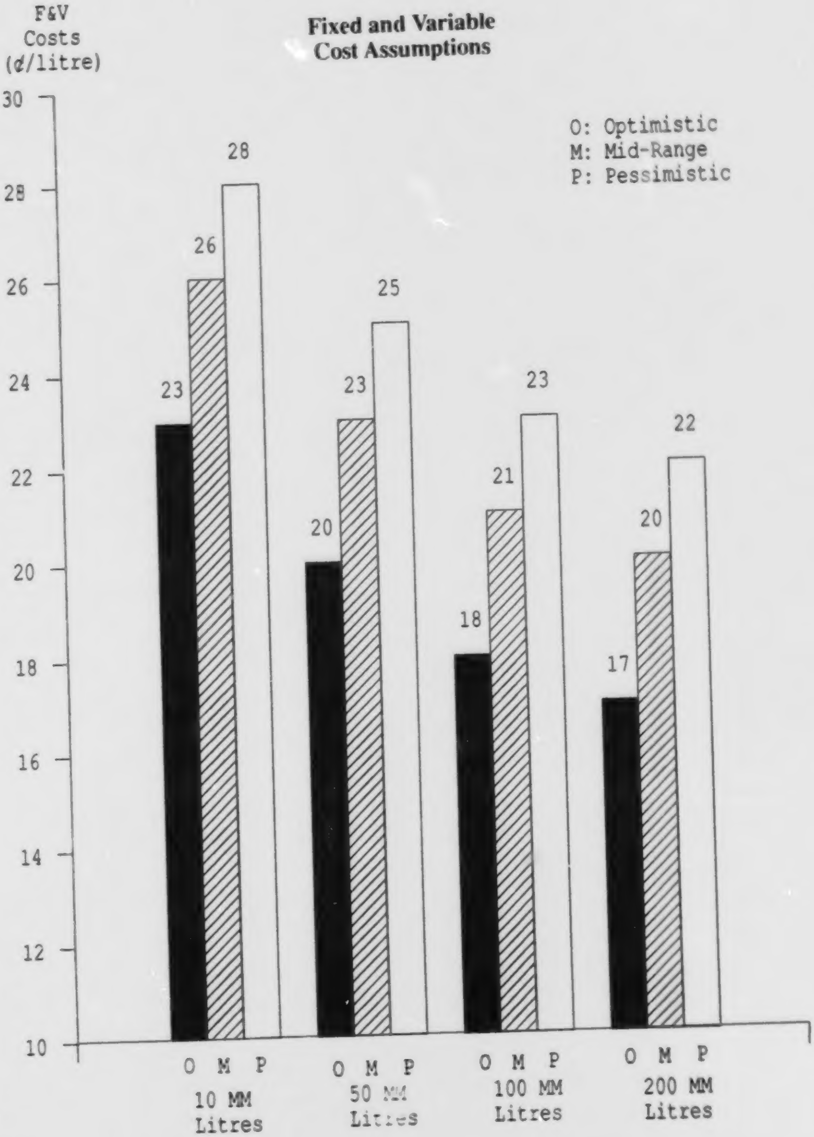
Capital Cost Assumptions



SOURCE: Canadian Energy Research Institute.

Figure B.2

Fixed and Variable Cost Assumptions



SOURCE: Canadian Energy Research Institute.

ETHANOL PLANT MODEL

BASE CASES

ETHANOL PRICE $0.30, $0.35, AND $0.45/LITRE

10 MM LITRES PER YEAR WITH OPERATING COSTS $0.23, $0.26, AND $0.28/LITRE
50 MM LITRES PER YEAR WITH OPERATING COSTS $0.20, $0.23, AND $0.25/LITRE
100 MM LITRES PER YEAR WITH OPERATING COSTS $0.18, $0.21, AND $0.23/LITRE
200 MM LITRES PER YEAR WITH OPERATING COSTS $0.17, $0.20, AND $0.22/LITRE

CAPITAL COSTS OF $10, 12, AND 15 MILLION ON 10 MM LITRES
CAPITAL COSTS OF $35, 55, AND 75 MILLION ON 50 MM LITRES
CAPITAL COSTS OF $65, 90, AND 115 MILLION ON 100 MM LITRES
CAPITAL COSTS OF $120, 160, AND 200 MILLION ON 200 MM LITRES

DDG SOLD AT $170/TONNE
CO2 NOT SOLD
FEEDSTOCK AT $110/TONNE
ETHANOL YIELD OF 350 LITRES/TONNE

100%EQUITY
0% SALVAGE

NO INFLATION

FEDERAL TAX AT 28.8%
PROVINCIAL TAX AT 16%
TOTAL TAX AT 44.8%

NO GOVERNMENT SUBSIDY
NO GOVERNMENT CAPITAL

MONDAY, OCTOBER 24, 1988.

10 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $10 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2700.00	4050.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3632.57	5448.86	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	3632.57	5448.86	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29
COSTS ($ 000)												
OPERATING	0.00	1380.00	2070.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3265.71	4898.57	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86
DEPRECIATION	0.00	1692.50	2881.33	1840.25	1060.80	704.29	489.20	345.04	245.32	175.67	126.79	10.36
TOTAL COSTS	0.00	4958.21	7779.90	7283.11	6503.66	6147.14	5932.05	5787.90	5688.18	5618.52	5569.65	5453.22
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-1325.64	-2331.04	-1228.83	-449.38	-92.86	122.23	266.39	366.10	435.76	484.63	601.07
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	54.76	119.34	164.01	195.22	217.12	269.28
NET INCOME	0.00	-1325.64	-2331.04	-1228.83	-449.38	-92.86	67.47	147.05	202.09	240.54	267.52	331.79
CAPITAL (-)	10000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	1692.50	2881.33	1840.25	1060.80	704.29	489.20	345.04	245.32	175.67	126.79	10.36
NET CASH FLOW	-10000.00	366.86	550.29	611.43	611.43	611.43	556.67	492.09	447.41	416.21	394.31	342.15
NET PRESENT VALUE AT 10%	-9534.63	-9216.64	-8783.02	-8345.03	-7946.85	-7584.87	-7285.26	-7044.50	-6845.49	-6677.19	-6532.24	-5726.75
NET PRESENT VALUE AT 15%	-9325.05	-9027.57	-8639.56	-8264.67	-7938.68	-7655.21	-7430.79	-7258.28	-7121.90	-7011.57	-6920.68	-6506.49
PRETAX CASH FLOW	-10000.00	366.86	550.29	611.43	611.43	611.43	611.43	611.43	611.43	611.43	611.43	611.43
NET PRESENT VALUE AT 10%	-9534.63	-9216.64	-8783.02	-8345.03	-7946.85	-7584.87	-7255.79	-6956.63	-6684.67	-6437.43	-6212.67	-4831.61
NET PRESENT VALUE AT 15%	-9325.05	-9027.57	-8639.56	-8264.67	-7938.68	-7655.21	-7408.72	-7194.37	-7007.99	-6845.91	-6704.98	-5997.66
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.282	0.320	0.184	0.106	0.070	0.049	0.035	0.025	0.018	0.013	0.110
UNIT TOTAL COSTS	0.000	0.826	0.864	0.728	0.650	0.615	0.593	0.579	0.569	0.562	0.557	0.654
UNIT PROFIT BEFORE TAX	0.000	-0.221	-0.259	-0.123	-0.045	-0.009	0.012	0.027	0.037	0.044	0.048	-0.049
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.005	0.012	0.016	0.020	0.022	0.008
UNIT PROFIT AFTER TAX ($)		-0.221	-0.259	-0.123	-0.045	-0.009	0.007	0.015	0.020	0.024	0.027	-0.056

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	-54.76	-119.34	-164.01	-195.22	-217.12	-269.28
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	-54.76	-174.10	-338.12	-533.34	-750.45	-3328.89
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	-20.59	-59.60	-106.22	-154.48	-201.15	-474.49

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

10 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $12 MILLION - FIXED AND VARIABLE COSTS $0.26/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2400.00	3600.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3332.57	4998.86	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	3332.57	4998.86	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29
COSTS ($ 000)												
OPERATING	0.00	1560.00	2340.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3445.71	5168.57	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86
DEPRECIATION	0.00	2031.00	3457.59	2208.31	1272.97	845.14	587.04	414.05	294.39	210.80	152.15	12.43
TOTAL COSTS	0.00	5476.71	8626.16	7951.16	7015.82	6588.00	6329.89	6156.91	6037.25	5953.66	5895.01	5755.29
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-2144.14	-3627.30	-2396.88	-1461.54	-1033.72	-775.61	-602.62	-482.96	-399.37	-340.73	-201.01
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-2144.14	-3627.30	-2396.88	-1461.54	-1033.72	-775.61	-602.62	-482.96	-399.37	-340.73	-201.01
CAPITAL (-)	12000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	2031.00	3457.59	2208.31	1272.97	845.14	587.04	414.05	294.39	210.80	152.15	12.43
NET CASH FLOW	-12000.00	-113.14	-169.71	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57
NET PRESENT VALUE AT 10%	-11441.55	-11539.62	-11673.35	-11808.44	-11931.24	-12042.88	-12144.37	-12236.63	-12320.51	-12396.76	-12466.08	-12892.01
NET PRESENT VALUE AT 15%	-11190.06	-11281.80	-11401.47	-11517.09	-11617.63	-11705.05	-11781.08	-11847.18	-11904.67	-11954.65	-11998.12	-12216.26
PRETAX CASH FLOW	-12000.00	-113.14	-169.71	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57
NET PRESENT VALUE AT 10%	-11441.55	-11539.62	-11673.35	-11808.44	-11931.24	-12042.88	-12144.37	-12236.63	-12320.51	-12396.76	-12466.08	-12892.01
NET PRESENT VALUE AT 15%	-11190.06	-11281.80	-11401.47	-11517.09	-11617.63	-11705.05	-11781.08	-11847.18	-11904.67	-11954.65	-11998.12	-12216.26
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260
UNIT DEPRECIATION		0.339	0.384	0.221	0.127	0.085	0.059	0.041	0.029	0.021	0.015	0.132
UNIT TOTAL COSTS	0.000	0.913	0.958	0.795	0.702	0.659	0.633	0.616	0.604	0.595	0.590	0.706
UNIT PROFIT BEFORE TAX	0.000	-0.357	-0.403	-0.240	-0.146	-0.103	-0.078	-0.060	-0.048	-0.040	-0.034	-0.151
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.357	-0.403	-0.240	-0.146	-0.103	-0.078	-0.060	-0.048	-0.040	-0.034	-0.151

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

10 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $15 MILLION - FIXED AND VARIABLE COSTS $0.28/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2100.00	3150.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3032.57	4548.86	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	3032.57	4548.86	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29
COSTS ($ 000)												
OPERATING	0.00	1680.00	2520.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3565.71	5348.57	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86
DEPRECIATION	0.00	2538.75	4321.99	2760.38	1591.21	1056.43	733.80	517.56	367.99	263.50	190.19	15.54
TOTAL COSTS	0.00	6104.46	9670.56	8703.24	7534.06	6999.29	6676.65	6460.42	6310.84	6206.36	6133.05	5958.40
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-3071.89	-5121.70	-3648.95	-2479.78	-1945.00	-1622.37	-1406.13	-1256.56	-1152.07	-1078.76	-904.11
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-3071.89	-5121.70	-3648.95	-2479.78	-1945.00	-1622.37	-1406.13	-1256.56	-1152.07	-1078.76	-904.11
CAPITAL (-)	15000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	2538.75	4321.99	2760.38	1591.21	1056.43	733.80	517.56	367.99	263.50	190.19	15.54
NET CASH FLOW	-15000.00	-533.14	-799.71	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57
NET PRESENT VALUE AT 10%	-14301.94	-14764.06	-15394.22	-16030.75	-16609.41	-17135.42	-17613.70	-18048.46	-18443.69	-18803.00	-19129.64	-21136.70
NET PRESENT VALUE AT 15%	-13987.57	-14419.88	-14983.77	-15528.58	-16002.34	-16414.30	-16772.52	-17084.02	-17354.89	-17590.43	-17795.25	-18823.17
PRETAX CASH FLOW	-15000.00	-533.14	-799.71	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57
NET PRESENT VALUE AT 10%	-14301.94	-14764.06	-15394.22	-16030.75	-16609.41	-17135.47	-17613.70	-18048.46	-18443.69	-18803.00	-19129.64	-21136.70
NET PRESENT VALUE AT 15%	-13987.57	-14419.88	-14983.77	-15528.58	-16002.34	-16414.30	-16772.52	-17084.02	-17354.89	-17590.43	-17795.25	-18823.17
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280
UNIT DEPRECIATION		0.423	0.480	0.276	0.159	0.106	0.073	0.052	0.037	0.026	0.019	0.165
UNIT TOTAL COSTS	0.000	1.017	1.075	0.870	0.753	0.700	0.668	0.646	0.631	0.621	0.613	0.759
UNIT PROFIT BEFORE TAX	0.000	-0.512	-0.569	-0.365	-0.248	-0.195	-0.162	-0.141	-0.126	-0.115	-0.108	-0.254
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.512	-0.569	-0.365	-0.248	-0.195	-0.162	-0.141	-0.126	-0.115	-0.108	-0.254

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $35 MILLION - FIXED AND VARIABLE COSTS $0.20/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	13500.00	20250.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	18162.86	27244.29	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	18162.86	27244.29	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43
COSTS ($ 000)												
OPERATING	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	15428.57	23142.86	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29
DEPRECIATION	0.00	5923.75	10084.64	6440.89	3712.82	2465.00	1712.19	1207.65	858.64	614.83	443.78	36.27
TOTAL COSTS	0.00	21352.32	33227.49	32155.18	29427.10	28179.29	27426.48	26921.93	26572.92	26329.12	26158.07	25750.55
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-3189.46	-5983.21	-1883.75	844.33	2092.14	2844.95	3349.50	3698.51	3942.31	4113.36	4520.88
INCOME TAXES	0.00	0.00	0.00	0.00	378.26	937.28	1274.54	1500.57	1656.93	1766.16	1842.79	2025.35
NET INCOME	0.00	-3189.46	-5983.21	-1883.75	466.07	1154.86	1570.41	1848.92	2041.58	2176.16	2270.57	2495.52
CAPITAL (-)	35000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	5923.75	10084.64	6440.89	3712.82	2465.00	1712.19	1207.65	858.64	614.83	443.78	36.27
NET CASH FLOW	-35000.00	2734.29	4101.43	4557.14	4178.88	3619.86	3282.60	3056.57	2900.21	2790.99	2714.36	2531.79
NET PRESENT VALUE AT 10%	-33371.19	-31001.16	-27769.29	-24504.78	-21783.37	-19640.32	-17873.61	-16378.10	-15088.09	-13959.52	-12961.72	-7128.75
NET PRESENT VALUE AT 15%	-32637.67	-30420.51	-27528.56	-24734.41	-22506.38	-20828.14	-19504.77	-18433.25	-17549.15	-16809.33	-16183.67	-13190.50
PRETAX CASH FLOW	-35000.00	2734.29	4101.43	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14
NET PRESENT VALUE AT 10%	-33371.19	-31001.16	-27769.29	-24504.78	-21537.04	-18839.09	-16386.42	-14156.71	-12129.71	-10286.98	-8611.77	1681.68
NET PRESENT VALUE AT 15%	-32637.67	-30420.51	-27528.56	-24734.41	-22304.71	-20191.93	-18354.73	-16757.16	-15367.97	-14159.98	-13109.56	-7837.71

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
UNIT DEPRECIATION		0.197	0.224	0.129	0.074	0.049	0.034	0.024	0.017	0.012	0.009	0.077
UNIT TOTAL COSTS	0.000	0.712	0.738	0.643	0.589	0.564	0.549	0.538	0.531	0.527	0.523	0.591
UNIT PROFIT BEFORE TAX	0.000	-0.106	-0.133	-0.038	0.017	0.042	0.057	0.067	0.074	0.079	0.082	0.014
UNIT INCOME TAX		0.000	0.000	0.000	0.008	0.019	0.025	0.030	0.033	0.035	0.037	0.019
UNIT PROFIT AFTER TAX ($)		-0.106	-0.133	-0.038	0.009	0.023	0.031	0.037	0.041	0.044	0.045	-0.005

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-378.26	-937.28	-1274.54	-1500.57	-1656.93	-1766.16	-1842.79	-2025.35
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-378.26	-1315.54	-2590.08	-4090.65	-5747.58	-7513.74	-9356.52	-29209.85
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-188.06	-593.27	-1072.42	-1562.96	-2033.96	-2470.53	-2866.62	-4991.50

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $55 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	12000.00	18000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	16662.86	24994.29	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	16662.86	24994.29	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43
COSTS ($ 000)												
OPERATING	0.00	6900.00	10350.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	16328.57	24492.86	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29
DEPRECIATION	0.00	9308.75	15847.29	10121.40	5834.43	3873.58	2690.58	1897.73	1349.28	966.16	697.37	56.99
TOTAL COSTS	0.00	25637.32	40340.14	37335.69	33048.71	31087.86	29904.87	29112.02	28563.57	28180.45	27911.66	27271.27
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-8974.46	-15345.86	-9564.26	-5277.28	-3316.43	-2133.44	-1340.59	-792.14	-409.02	-140.23	500.15
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	224.07
NET INCOME	0.00	-8974.46	-15345.86	-9564.26	-5277.28	-3316.43	-2133.44	-1340.59	-792.14	-409.02	-140.23	276.09
CAPITAL (-)	55000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	9308.75	15847.29	10121.40	5834.43	3873.58	2690.58	1897.73	1349.28	966.16	697.37	56.99
NET CASH FLOW	-55000.00	334.29	501.43	557.14	557.14	557.14	557.14	557.14	557.14	557.14	557.14	333.07
NET PRESENT VALUE AT 10%	-52440.44	-52150.69	-51755.57	-51356.46	-50993.63	-50663.79	-50363.93	-50091.34	-49843.52	-49618.23	-49413.43	-48481.49
NET PRESENT VALUE AT 15%	-51287.76	-51016.70	-50663.14	-50321.53	-50024.49	-49766.18	-49541.57	-49346.26	-49176.42	-49028.74	-48900.32	-48413.94
PRETAX CASH FLOW	-55000.00	334.29	501.43	557.14	557.14	557.14	557.14	557.14	557.14	557.14	557.14	557.14
NET PRESENT VALUE AT 10%	-52440.44	-52150.69	-51755.57	-51356.46	-50993.63	-50663.79	-50363.93	-50091.34	-49843.52	-49618.23	-49413.43	-48154.98
NET PRESENT VALUE AT 15%	-51287.76	-51016.70	-50663.14	-50321.53	-50024.49	-49766.18	-49541.57	-49346.26	-49176.42	-49028.74	-48900.32	-48255.80
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.310	0.352	0.202	0.117	0.077	0.054	0.038	0.027	0.019	0.014	0.121
UNIT TOTAL COSTS	0.000	0.855	0.896	0.747	0.661	0.622	0.598	0.582	0.571	0.564	0.558	0.665
UNIT PROFIT BEFORE TAX	0.000	-0.299	-0.341	-0.191	-0.106	-0.066	-0.043	-0.027	-0.016	-0.008	-0.003	-0.110
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.299	-0.341	-0.191	-0.106	-0.066	-0.043	-0.027	-0.016	-0.008	-0.003	-0.110

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-224.07
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1611.80
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-147.47

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $75 MILLION - FIXED AND VARIABLE COSTS $0.25/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	10500.00	15750.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	15162.86	22744.29	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	15162.86	22744.29	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43
COSTS ($ 000)												
OPERATING	0.00	7500.00	11250.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	16928.57	25392.86	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29
DEPRECIATION	0.00	12693.75	21609.94	13801.91	7956.04	5282.15	3668.98	2587.82	1839.93	1317.50	950.96	77.71
TOTAL COSTS	0.00	29622.32	47002.79	42016.20	36170.32	33496.44	31883.26	30802.10	30054.22	29531.78	29165.25	28292.00
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-14459.46	-24258.51	-16744.77	-10898.89	-8225.01	-6611.83	-5530.67	-4782.79	-4260.35	-3893.82	-3020.57
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-14459.46	-24258.51	-16744.77	-10898.89	-8225.01	-6611.83	-5530.67	-4782.79	-4260.35	-3893.82	-3020.57
CAPITAL (-)	75000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	12693.75	21609.94	13801.91	7956.04	5282.15	3668.98	2587.82	1839.93	1317.50	950.96	77.71
NET CASH FLOW	-75000.00	-1765.71	-2648.57	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86
NET PRESENT VALUE AT 10%	-71509.69	-73040.19	-75127.22	-77235.34	-79151.81	-80894.06	-82477.92	-83917.79	-85226.76	-[illegible]16.74	-87498.54	-94145.72
NET PRESENT VALUE AT 15%	-69937.86	-71369.63	-73237.16	-75041.53	-76610.56	-77974.92	-79161.33	-80192.99	-81090.08	-81870.16	-82548.49	-85952.88
PRETAX CASH FLOW	-75000.00	-1765.71	-2648.57	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86
NET PRESENT VALUE AT 10%	-71509.69	-73040.19	-75127.22	-77235.34	-79151.81	-80894.06	-82477.92	-83917.79	-85226.76	-86416.74	-87498.54	-94145.72
NET PRESENT VALUE AT 15%	-69937.86	-71369.63	-73237.16	-75041.53	-76610.56	-77974.92	-79161.33	-80192.99	-81090.08	-81870.16	-82548.49	-85952.88

RATE OF RETURN ON NET CASH FLOW

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
UNIT DEPRECIATION		0.423	0.480	0.276	0.159	0.106	0.073	0.052	0.037	0.026	0.019	0.165
UNIT TOTAL COSTS	0.000	0.987	1.045	0.840	0.723	0.670	0.638	0.616	0.601	0.591	0.583	0.729
UNIT PROFIT BEFORE TAX	0.000	-0.482	-0.539	-0.335	-0.218	-0.165	-0.132	-0.111	-0.096	-0.085	-0.078	-0.224
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.482	-0.539	-0.335	-0.218	-0.165	-0.132	-0.111	-0.096	-0.085	-0.078	-0.224

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $65 MILLION - FIXED AND VARIABLE COSTS $0.18/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	27000.00	40500.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	36325.71	54488.57	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	36325.71	54488.57	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86
COSTS ($ 000)												
OPERATING	0.00	10800.00	16200.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	29657.14	44485.71	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57
DEPRECIATION	0.00	11001.25	18728.61	11961.66	6895.23	4577.86	3179.78	2242.77	1594.61	1141.83	824.17	67.35
TOTAL COSTS	0.00	40658.39	63214.33	61390.23	56323.80	54006.43	52608.35	51671.34	51023.18	50570.40	50252.74	49495.92
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-4332.68	-8725.76	-847.37	4219.05	6536.42	7934.51	8871.51	9519.68	9972.45	10290.12	11046.94
INCOME TAXES	0.00	0.00	0.00	0.00	1890.14	2928.32	3554.66	3974.44	4264.82	4467.66	4609.97	4949.03
NET INCOME	0.00	-4332.68	-8725.76	-847.37	2328.92	3608.11	4379.85	4897.07	5254.86	5504.79	5680.15	6097.91
CAPITAL (-)	65000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	11001.25	18728.61	11961.66	6895.23	4577.86	3179.78	2242.77	1594.61	1141.83	824.17	67.35
NET CASH FLOW	-65000.00	6668.57	10002.86	11114.29	9224.15	8185.97	7559.63	7139.85	6849.47	6646.63	6504.31	6165.26
NET PRESENT VALUE AT 10%	-61975.07	-56194.86	-48312.75	-40351.02	-34344.00	-29497.70	-25429.07	-21935.71	-18889.08	-16201.45	-13810.45	327.58
NET PRESENT VALUE AT 15%	-60612.81	-55205.44	-48152.35	-41337.77	-36419.80	-32624.62	-29576.98	-27074.01	-24986.04	-23224.17	-21724.92	-14473.33
PRETAX CASH FLOW	-65000.00	6668.57	10002.86	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29
NET PRESENT VALUE AT 10%	-61975.07	-56194.86	-48312.75	-40351.02	-33113.09	-26533.15	-20551.39	-15113.43	-10169.82	-5675.64	-1590.01	23514.38
NET PRESENT VALUE AT 15%	-60612.81	-55205.44	-48152.35	-41337.77	-35412.05	-30259.25	-25778.55	-21882.29	-18494.24	-15548.11	-12986.26	-128.91
RATE OF RETURN ON NET CASH FLOW									0.01	0.03	0.04	0.10

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
UNIT DEPRECIATION		0.183	0.208	0.120	0.069	0.046	0.032	0.022	0.016	0.011	0.008	0.072
UNIT TOTAL COSTS	0.000	0.678	0.702	0.614	0.563	0.540	0.526	0.517	0.510	0.506	0.503	0.566
UNIT PROFIT BEFORE TAX	0.000	-0.072	-0.097	-0.008	0.042	0.065	0.079	0.089	0.095	0.100	0.103	0.040
UNIT INCOME TAX		0.000	0.000	0.000	0.019	0.029	0.036	0.040	0.043	0.045	0.046	0.026
UNIT PROFIT AFTER TAX ($)		-0.072	-0.097	-0.008	0.023	0.036	0.044	0.049	0.053	0.055	0.057	0.014

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-1890.14	-2928.32	-3554.66	-3974.44	-4264.82	-4467.66	-4609.97	-4949.03
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-1890.14	-4818.45	-8373.11	-12347.55	-16612.36	-21080.02	-25690.00	-74437.03
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-939.73	-2205.72	-3542.05	-4841.30	-6053.63	-7157.97	-8148.85	-13376.24

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $90 MILLION - FIXED AND VARIABLE COSTS $0.21/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	20857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	24000.00	36000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	33325.71	49988.57	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	33325.71	49988.57	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86
COSTS ($ 000)												
OPERATING	0.00	12600.00	18900.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	31457.14	47185.71	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57
DEPRECIATION	0.00	15232.50	25931.93	16562.29	9547.24	6338.58	4402.77	3105.38	2207.92	1581.00	1141.15	93.25
TOTAL COSTS	0.00	46689.64	73117.64	68990.87	61975.82	58767.15	56831.34	55533.95	54636.49	54009.57	53569.73	52521.83
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-13363.93	-23129.07	-13448.01	-6432.96	-3224.29	-1288.49	8.91	906.37	1533.29	1973.13	3021.03
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.99	406.05	686.91	883.96	1353.42
NET INCOME	0.00	-13363.93	-23129.07	-13448.01	-6432.96	-3224.29	-1288.49	4.92	500.31	846.38	1089.17	1667.61
CAPITAL (-)	90000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	15232.50	25931.93	16562.29	9547.24	6338.58	4402.77	3105.38	2207.92	1581.00	1141.15	93.25
NET CASH FLOW	-90000.00	1868.57	2802.86	3114.29	3114.29	3114.29	3114.29	3110.30	2708.23	2427.37	2230.32	1760.86
NET PRESENT VALUE AT 10%	-85811.63	-84191.98	-81983.37	-79752.45	-77724.34	-75880.61	-74204.48	-72682.69	-71478.07	-70496.54	-69676.67	-65405.42
NET PRESENT VALUE AT 15%	-83925.43	-82410.26	-80433.94	-78524.46	-76864.04	-75420.19	-74164.68	-73074.32	-72248.75	-71605.31	-71091.22	-68888.83
PRETAX CASH FLOW	-90000.00	1868.57	2802.86	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29
NET PRESENT VALUE AT 10%	-85811.63	-84191.98	-81983.37	-79752.45	-77724.34	-75880.61	-74204.48	-72680.74	-71295.51	-70036.21	-68891.40	-61857.01
NET PRESENT VALUE AT 15%	-83925.43	-82410.26	-80433.94	-78524.46	-76864.04	-75420.19	-74164.68	-73072.92	-72123.57	-71298.05	-70580.20	-66977.50

RATE OF RETURN ON NET CASH FLOW

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210
UNIT DEPRECIATION		0.254	0.288	0.166	0.095	0.063	0.044	0.031	0.022	0.016	0.011	0.099
UNIT TOTAL COSTS	0.000	0.778	0.812	0.690	0.620	0.588	0.568	0.555	0.546	0.540	0.536	0.623
UNIT PROFIT BEFORE TAX	0.000	-0.223	-0.257	-0.134	-0.064	-0.032	-0.013	0.000	0.009	0.015	0.020	-0.068
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.007	0.009	0.002
UNIT PROFIT AFTER TAX ($)		-0.223	-0.257	-0.134	-0.064	-0.032	-0.013	0.000	0.005	0.008	0.011	-0.070

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.99	-406.05	-686.91	-883.96	-1353.42
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.99	-410.04	-1096.96	-1980.92	-14486.04
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.30	-116.73	-286.52	-476.53	-1782.32

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $115 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	21000.00	31500.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	30325.71	45488.57	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	30325.71	45488.57	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86
COSTS ($ 000)												
OPERATING	0.00	13800.00	20700.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	32657.14	48985.71	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57
DEPRECIATION	0.00	19463.75	33135.24	21162.93	12199.26	8099.30	5625.76	3967.98	2821.23	2020.16	1458.14	119.16
TOTAL COSTS	0.00	52120.89	82120.95	75591.50	66627.83	62527.87	60054.34	58396.56	57249.80	56448.73	55886.71	54547.73
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-21795.18	-36632.38	-25048.65	-16084.97	-11985.01	-9511.48	-7853.70	-6706.95	-5905.88	-5343.86	-4004.87
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-21795.18	-36632.38	-25048.65	-16084.97	-11985.01	-9511.48	-7853.70	-6706.95	-5905.88	-5343.86	-4004.87
CAPITAL (-)	115000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	19463.75	33135.24	21162.93	12199.26	8099.30	5625.76	3967.98	2821.23	2020.16	1458.14	119.16
NET CASH FLOW	-115000.00	-2331.43	-3497.14	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71
NET PRESENT VALUE AT 10%	-109648.20	-111669.04	-114424.74	-117208.27	-119738.76	-122039.20	-124130.51	-126031.70	-127760.06	-129331.29	-130759.68	-139536.54
NET PRESENT VALUE AT 15%	-107238.05	-109128.55	-111594.41	-113976.88	-116048.60	-117850.10	-119416.61	-120778.80	-121963.31	-122993.32	-123888.98	-128384.10
PRETAX CASH FLOW	-115000.00	-2331.43	-3497.14	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71
NET PRESENT VALUE AT 10%	-109648.20	-111669.04	-114424.74	-117208.27	-119738.76	-122039.20	-124130.51	-126031.70	-127760.06	-129331.29	-130759.68	-139536.54
NET PRESENT VALUE AT 15%	-107238.05	-109128.55	-111594.41	-113976.88	-116048.60	-117850.10	-119416.61	-120778.80	-121963.31	-122993.32	-123888.98	-128384.10
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.324	0.368	0.212	0.122	0.081	0.056	0.040	0.028	0.020	0.015	0.127
UNIT TOTAL COSTS	0.000	0.869	0.912	0.756	0.666	0.625	0.601	0.584	0.572	0.564	0.559	0.671
UNIT PROFIT BEFORE TAX	0.000	-0.363	-0.407	-0.250	-0.161	-0.120	-0.095	-0.079	-0.067	-0.059	-0.053	-0.165
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.363	-0.407	-0.250	-0.161	-0.120	-0.095	-0.079	-0.067	-0.059	-0.053	-0.165

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $120 MILLION - FIXED AND VARIABLE COSTS $0.17/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	54000.00	81000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	72651.43	108977.14	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	72651.43	108977.14	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71
COSTS ($ 000)												
OPERATING	0.00	20400.00	30600.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	58114.29	87171.43	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14
DEPRECIATION	0.00	20310.00	34575.90	22083.06	12729.66	8451.44	5870.36	4140.50	2943.89	2108.00	1521.54	124.34
TOTAL COSTS	0.00	78424.29	121747.33	118940.20	109586.80	105308.58	102727.51	100997.65	99801.04	98965.14	98378.68	96981.48
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-5772.86	-12770.19	2145.51	11498.91	15777.13	18358.21	20088.07	21284.68	22120.58	22707.03	24104.23
INCOME TAXES	0.00	0.00	0.00	961.19	5151.51	7068.16	8224.48	8999.45	9535.54	9910.02	10172.75	10798.70
NET INCOME	0.00	-5772.86	-12770.19	1184.32	6347.40	8708.98	10133.73	11088.61	11749.14	12210.56	12534.28	13305.54
CAPITAL (-)	120000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	20310.00	34575.90	22083.06	12729.66	8451.44	5870.36	4140.50	2943.89	2108.00	1521.54	124.34
NET CASH FLOW	-120000.00	14537.14	21805.71	23267.38	19077.06	17160.42	16004.09	15229.12	14693.04	14318.55	14055.82	13429.88
NET PRESENT VALUE AT 10%	-114415.51	-101814.95	-84632.36	-67964.75	-55541.24	-45381.84	-36768.36	-29317.11	-22781.68	-16991.82	-11824.88	18901.71
NET PRESENT VALUE AT 15%	-111900.58	-100112.79	-84737.41	-70471.32	-60300.15	-52344.24	-45892.23	-40553.46	-36074.47	-32278.97	-29039.09	-13282.50
PRETAX CASH FLOW	-120000.00	14537.14	21805.71	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57
NET PRESENT VALUE AT 10%	-114415.51	-101814.95	-84632.36	-67276.21	-51497.89	-37153.96	-24114.03	-12259.54	-1482.74	8314.35	17220.80	71947.08
NET PRESENT VALUE AT 15%	-111900.58	-100112.79	-84737.41	-69881.98	-56964.21	-45731.37	-35963.68	-27470.03	-20084.26	-13661.84	-8077.14	19951.22
								0.02	0.04	0.06	0.07	0.13

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
UNIT DEPRECIATION		0.169	0.192	0.110	0.064	0.042	0.029	0.021	0.015	0.011	0.008	0.066
UNIT TOTAL COSTS	0.000	0.654	0.676	0.595	0.548	0.527	0.514	0.505	0.499	0.495	0.492	0.550
UNIT PROFIT BEFORE TAX	0.000	-0.048	-0.071	0.011	0.057	0.079	0.092	0.100	0.106	0.111	0.114	0.055
UNIT INCOME TAX		0.000	0.000	0.005	0.026	0.035	0.041	0.045	0.048	0.050	0.051	0.030
UNIT PROFIT AFTER TAX ($)		-0.048	-0.071	0.006	0.032	0.044	0.051	0.055	0.059	0.061	0.063	0.025

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	-961.19	-5151.51	-7068.16	-8224.48	-8999.45	-9535.54	-9910.02	-10172.75	-10798.70
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	-961.19	-6112.70	-13180.86	-21405.33	-30404.79	-39940.32	-49850.34	-60023.09	-166637.92
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	-549.56	-3110.78	-6166.53	-9258.42	-12200.36	-14910.95	-17360.56	-19547.12	-30990.60

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $160 MILLION - FIXED AND VARIABLE COSTS $0.20/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	48000.00	72000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	66651.43	99977.14	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	66651.43	99977.14	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71
COSTS ($ 000)												
OPERATING	0.00	24000.00	36000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	61714.29	92571.43	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14
DEPRECIATION	0.00	27080.00	46101.20	29444.08	16972.88	11268.59	7827.15	5520.67	3925.19	2810.66	2028.72	165.79
TOTAL COSTS	0.00	88794.29	138672.63	132301.22	119830.02	114125.73	110684.29	108377.82	106782.33	105667.80	104885.86	103022.93
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-22142.86	-38695.49	-21215.51	-8744.31	-3040.01	401.42	2707.90	4303.38	5417.91	6199.85	8062.79
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	179.84	1213.14	1927.91	2427.22	2777.53	3612.13
NET INCOME	0.00	-22142.86	-38695.49	-21215.51	-8744.31	-3040.01	221.58	1494.76	2375.47	2990.69	3422.32	4450.66
CAPITAL (-)	160000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	27080.00	46101.20	29444.08	16972.88	11268.59	7827.15	5520.67	3925.19	2810.66	2028.72	165.79
NET CASH FLOW	-160000.00	4937.14	7405.71	8228.57	8228.57	8228.57	8048.74	7015.43	6300.66	5801.35	5451.04	4616.44
NET PRESENT VALUE AT 10%	-152554.01	-148274.58	-142438.98	-136544.44	-131185.76	-126314.24	-121982.37	-118549.88	-115747.37	-113401.53	-111397.72	-100447.84
NET PRESENT VALUE AT 15%	-149200.77	-145197.37	-139975.54	-134930.30	-130543.14	-126728.21	-123483.38	-121024.03	-119103.35	-117565.55	-116309.08	-110674.64
PRETAX CASH FLOW	-160000.00	4937.14	7405.71	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57
NET PRESENT VALUE AT 10%	-152554.01	-148274.58	-142438.98	-136544.44	-131185.76	-126314.24	-121885.59	-117859.53	-114199.49	-110872.17	-107847.34	-89261.06
NET PRESENT VALUE AT 15%	-149200.77	-145197.37	-139975.54	-134930.30	-130543.14	-126728.21	-123410.88	-120526.25	-118017.87	-115836.67	-113939.98	-104420.91

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
UNIT DEPRECIATION		0.226	0.256	0.147	0.085	0.056	0.039	0.028	0.020	0.014	0.010	0.088
UNIT TOTAL COSTS	0.000	0.740	0.770	0.662	0.599	0.571	0.553	0.542	0.534	0.528	0.524	0.602
UNIT PROFIT BEFORE TAX	0.000	-0.185	-0.215	-0.106	-0.044	-0.015	0.002	0.014	0.022	0.027	0.031	-0.047
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.010	0.012	0.014	0.004
UNIT PROFIT AFTER TAX ($)		-0.185	-0.215	-0.106	-0.044	-0.015	0.001	0.007	0.012	0.015	0.017	-0.051

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	-179.84	-1213.14	-1927.91	-2427.22	-2777.53	-3612.13
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	-179.84	-1392.97	-3320.89	-5748.11	-8525.65	-42817.42
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	-67.61	-464.18	-1012.22	-1612.19	-2209.20	-5831.63

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $200 MILLION - FIXED AND VARIABLE COSTS $0.22/LITRE
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	42000.00	63000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	60651.43	90977.14	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	60651.43	90977.14	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71
COSTS ($ 000)												
OPERATING	0.00	26400.00	39600.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	64114.29	96171.43	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14
DEPRECIATION	0.00	33850.00	57626.50	36805.10	21216.10	14085.73	9783.94	6900.84	4906.49	3513.33	2535.90	207.23
TOTAL COSTS	0.00	97964.29	153797.93	143662.24	128073.24	120942.88	116641.08	113757.98	111763.63	110370.47	109393.04	107064.37
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-37312.86	-62820.79	-42576.53	-26987.53	-19857.16	-15555.37	-12672.27	-10677.92	-9284.76	-8307.33	-5978.66
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-37312.86	-62820.79	-42576.53	-26987.53	-19857.16	-15555.37	-12672.27	-10677.92	-9284.76	-8307.33	-5978.66
CAPITAL (-)	200000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	33850.00	57626.50	36805.10	21216.10	14085.73	9783.94	6900.84	4906.49	3513.33	2535.90	207.23
NET CASH FLOW	-200000.00	-3462.86	-5194.29	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43
NET PRESENT VALUE AT 10%	-190692.52	-193694.07	-197787.09	-201921.46	-205679.97	-209096.80	-212203.01	-215026.84	-217593.96	-219927.70	-222049.28	-235085.49
NET PRESENT VALUE AT 15%	-186500.96	-189308.90	-192971.43	-196510.11	-199587.22	-202262.97	-204589.70	-206612.95	-208372.30	-209902.17	-211232.49	-217909.06
PRETAX CASH FLOW	-200000.00	-3462.86	-5194.29	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43
NET PRESENT VALUE AT 10%	-190692.52	-193694.07	-197787.09	-201921.46	-205679.97	-209096.80	-212203.01	-215026.84	-217593.96	-219927.70	-222049.28	-235085.49
NET PRESENT VALUE AT 15%	-186500.96	-189308.90	-192971.43	-196510.11	-199587.22	-202262.97	-204589.70	-206612.95	-208372.30	-209902.17	-211232.49	-217909.06

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220
UNIT DEPRECIATION		0.282	0.320	0.184	0.106	0.070	0.049	0.035	0.025	0.018	0.013	0.110
UNIT TOTAL COSTS	0.000	0.816	0.854	0.718	0.640	0.605	0.583	0.569	0.559	0.552	0.547	0.644
UNIT PROFIT BEFORE TAX	0.000	-0.311	-0.349	-0.213	-0.135	-0.099	-0.078	-0.063	-0.053	-0.046	-0.042	-0.139
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.311	-0.349	-0.213	-0.135	-0.099	-0.078	-0.063	-0.053	-0.046	-0.042	-0.139

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

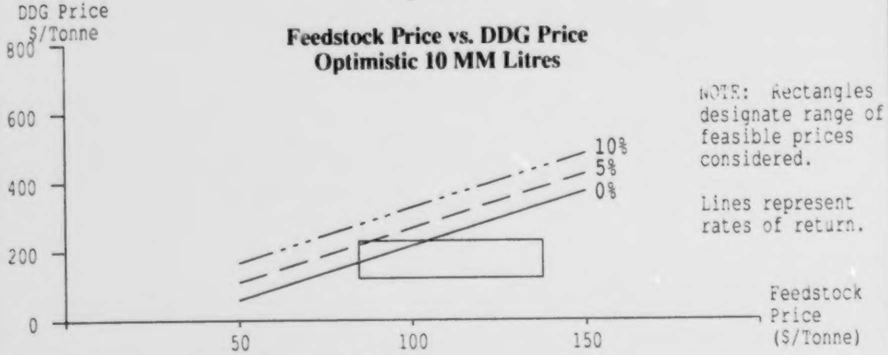
* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

APPENDIX C

ETHANOL SENSITIVITIES

Figure C.1

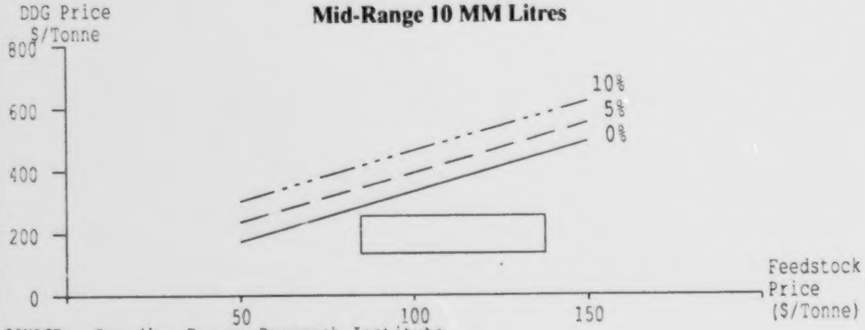


Feedstock Price vs. DDG Price
Optimistic 10 MM Litres

NOTE: Rectangles designate range of feasible prices considered.

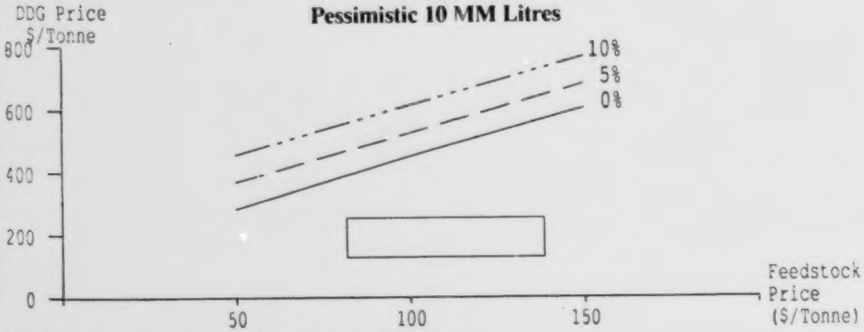
Lines represent rates of return.

SOURCE: Canadian Energy Research Institute.



Mid-Range 10 MM Litres

SOURCE: Canadian Energy Research Institute.



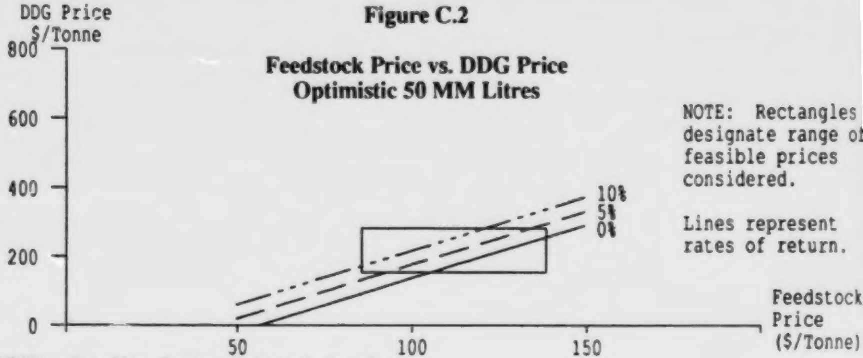
Pessimistic 10 MM Litres

SOURCE: Canadian Energy Research Institute.

Figure C.2

Feedstock Price vs. DDG Price

Optimistic 50 MM Litres

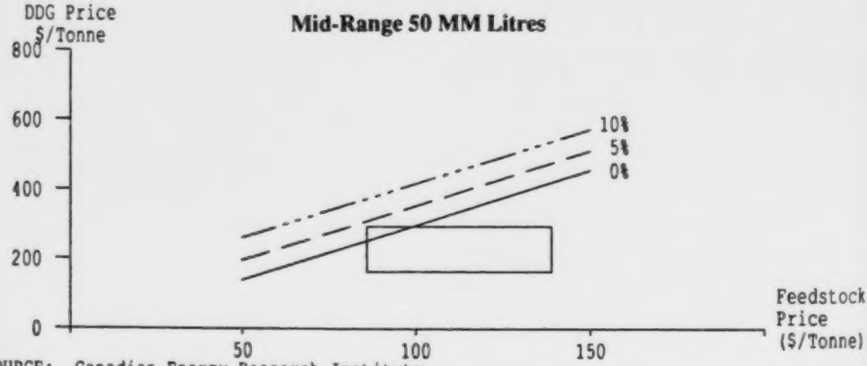


NOTE: Rectangles designate range o feasible prices considered.

Lines represent rates of return.

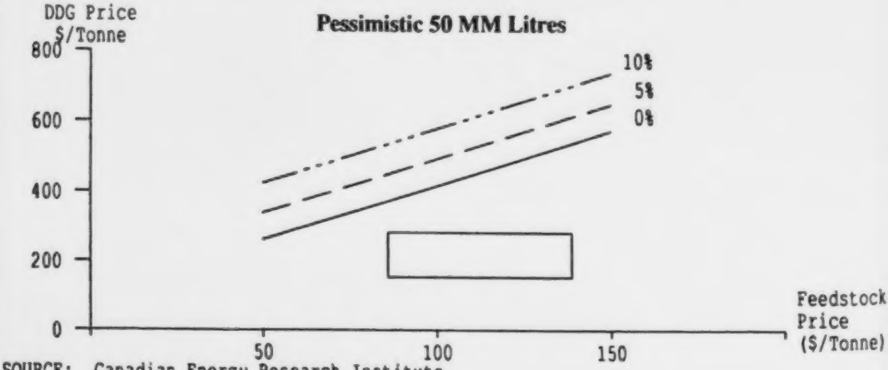
SOURCE: Canadian Energy Research Institute.

Mid-Range 50 MM Litres



SOURCE: Canadian Energy Research Institute.

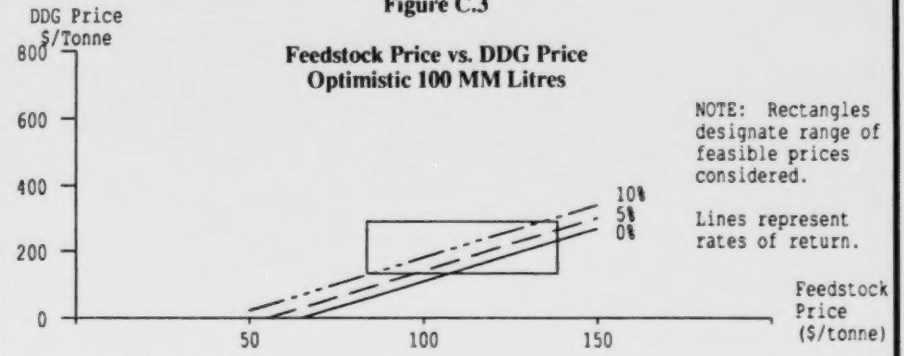
Pessimistic 50 MM Litres



SOURCE: Canadian Energy Research Institute.

Figure C.3

Feedstock Price vs. DDG Price
Optimistic 100 MM Litres

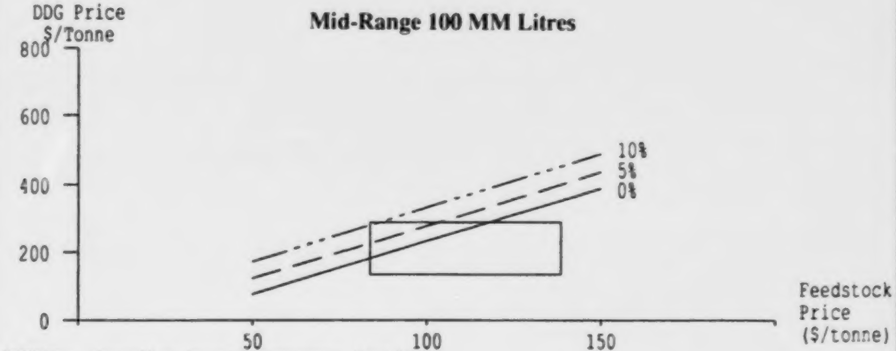


NOTE: Rectangles designate range of feasible prices considered.

Lines represent rates of return.

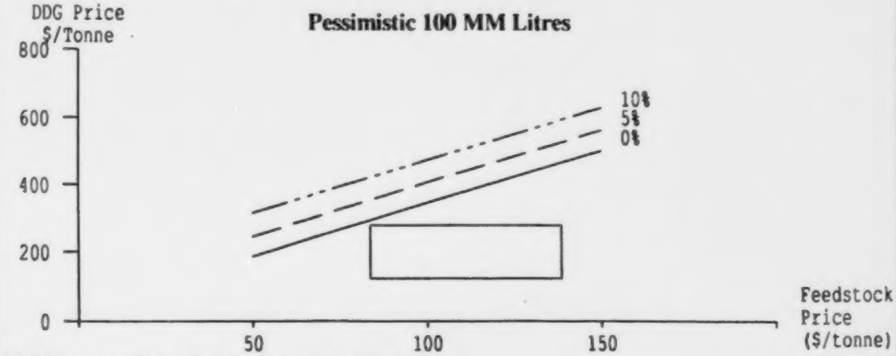
SOURCE: Canadian Energy Research Institute.

Mid-Range 100 MM Litres



SOURCE: Canadian Energy Research Institute.

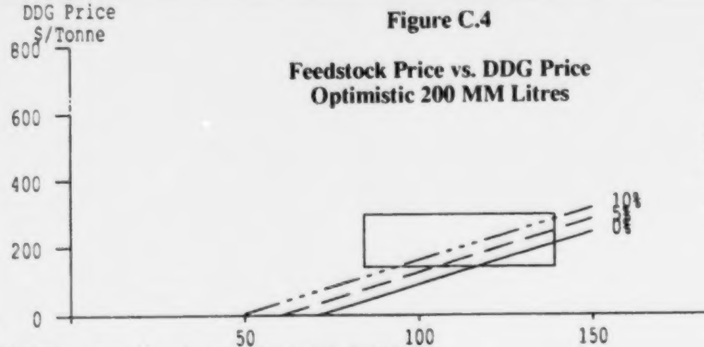
Pessimistic 100 MM Litres



SOURCE: Canadian Energy Research Institute.

Figure C.4

Feedstock Price vs. DDG Price
Optimistic 200 MM Litres

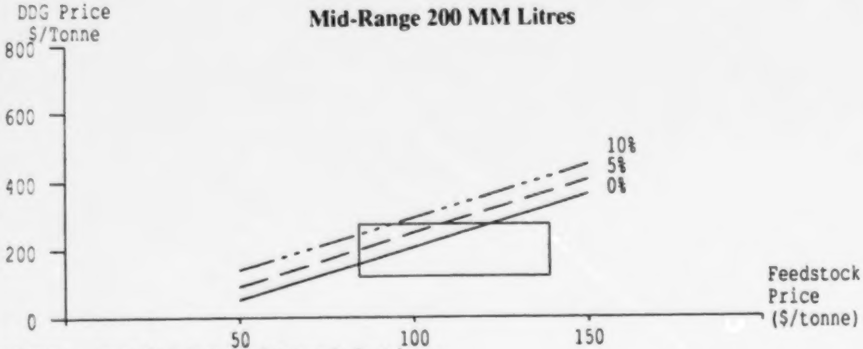


NOTE: Rectangles designate range of feasible prices considered.

Lines represent rates of return.

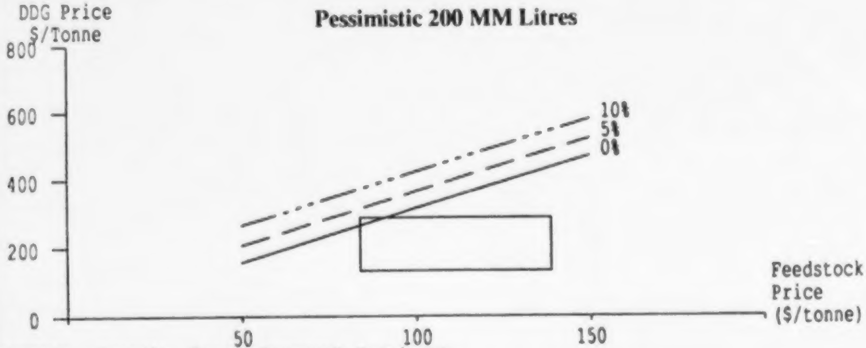
SOURCE: Canadian Energy Research Institute.

Mid-Range 200 MM Litres



SOURCE: Canadian Energy Research Institute.

Pessimistic 200 MM Litres



SOURCE: Canadian Energy Research Institute.

TABLE C.1

SENSITIVITY OF RATES OF RETURN TO FEEDSTOCK COSTS, UNDER VARYING PROJECT LIFE

(10, 50, 100,200 million litres/yr. plants)

	10		50		100		200	
Case Description	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)
Feed At $85/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	0	-	5	1	7
Optimistic	-	7	10	15	15	18	18	21
Base Case - Feed At $110/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	6	4	10	7	13
Feed At $140/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	-	-	-	-	-

SOURCE: Canadian Energy Research Institute.

TABLE C.2

SENSITIVITY OF RATES OF RETURN TO DDG PRICES, UNDER VARYING PROJECT LIFE
(10, 50, 100, 200 million litres/yr. plants)

Case Description	10		50		100		200	
	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)
DDG Prices at $280/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	3	1	8	5	11
Optimistic	3	9	14	18	18	21	21	24
DDG Prices at $220/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	2	-	4
Optimistic	-	4	7	12	11	16	14	18
Base Case - DDG Prices at $170/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	6	4	10	7	13
DDG Prices at $130/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	1	-	5	1	7

SOURCE: Canadian Energy Research Institute.

TABLE C.3

SENSITIVITY OF RATES OF RETURN TO ETHANOL YIELD, UNDER VARYING PROJECT LIFE

(10, 50, 100, 200 million litres/yr. plants)

Case Description	10		50		100		200	
	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)
Ethanol Yield 400 Litres/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	1
Optimistic	-	1	3	9	7	13	10	15
Base Case - Ethanol Yield 350 Litres/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	6	4	10	7	13
Ethanol Yield 300 Litres/Tonne								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	2	-	6	3	9

SOURCE: Canadian Energy Research Institute.

TABLE C.4

SENSITIVITY OF RATES OF RETURN – NO TAXES UNTIL PAYOUT, UNDER VARYING PROJECT LIFE
(10, 50, 100,200 million litres/yr. plants)

	10		50		100		200	
Case Description	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)	1998 (%)	2008 (%)
No Taxes Until Payout								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	0
Optimistic	-	1	2	8	6	11	9	14
Base Case								
Pessimistic	-	-	-	-	-	-	-	-
Mid-Range	-	-	-	-	-	-	-	-
Optimistic	-	-	-	6	4	10	7	13

SOURCE: Canadian Energy Research Institute.

C1 50% GOVERNMENT CAPITAL INVESTMENT CASES

ETHANOL PLANT MODEL

SENSITIVITY
50 PERCENT GOVERNMENT CAPITAL

ETHANOL PRICE $0.30, $0.35, AND $0.45/LITRE

10 MM LITRES PER YEAR WITH OPERATING COSTS $0.23, $0.26, AND $0.28/LITRE
50 MM LITRES PER YEAR WITH OPERATING COSTS $0.20, $0.23, AND $0.25/LITRE
100 MM LITRES PER YEAR WITH OPERATING COSTS $0.18, $0.21, AND $0.23/LITRE
200 MM LITRES PER YEAR WITH OPERATING COSTS $0.17, $0.20, AND $0.22/LITRE

CAPITAL COSTS OF $10, 12, AND 15 MILLION ON 10 MM LITRES
CAPITAL COSTS OF $35, 55, AND 75 MILLION ON 50 MM LITRES
CAPITAL COSTS OF $65, 90, AND 115 MILLION ON 100 MM LITRES
CAPITAL COSTS OF $120, 160, AND 200 MILLION ON 200 MM LITRES

DDG SOLD AT $170/TONNE
CO2 NOT SOLD
FEEDSTOCK AT $110/TONNE
ETHANOL YIELD OF 350 LITRES/TONNE

100%EQUITY
0% SALVAGE

NO INFLATION

FEDERAL TAX AT 28.8%
PROVINCIAL TAX AT 16%
TOTAL TAX AT 44.8%

NO GOVERNMENT SUBSIDY

TUESDAY, OCTOBER 25, 1988.

10 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $10 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
50 PERCENT GOVERNMENT CAPITAL

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2700.00	4050.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3632.57	5448.86	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	3632.57	5448.86	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29
COSTS ($ 000)												
OPERATING	0.00	1380.00	2070.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3265.71	4898.57	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86
DEPRECIATION	0.00	846.25	1440.66	920.13	530.40	352.14	244.60	172.52	122.66	87.83	63.40	5.18
TOTAL COSTS	0.00	4111.96	6339.23	6362.98	5973.26	5795.00	5687.46	5615.38	5565.52	5530.69	5506.25	5448.04
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-479.39	-890.38	-308.70	81.03	259.29	366.83	438.91	488.77	523.60	548.03	606.25
INCOME TAXES	0.00	0.00	0.00	0.00	36.30	116.16	164.34	196.63	218.97	234.57	245.52	271.60
NET INCOME	0.00	-479.39	-890.38	-308.70	44.73	143.13	202.49	242.28	269.80	289.02	302.51	334.65
CAPITAL (-)	10000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	846.25	1440.66	920.13	530.40	352.14	244.60	172.52	122.66	87.83	63.40	5.18
NET CASH FLOW	-5000.00	366.86	550.29	611.43	575.13	495.27	447.09	414.80	392.46	376.86	365.91	339.83
NET PRESENT VALUE AT 10%	-4767.31	-4449.33	-4015.71	-3577.71	-3203.17	-2909.96	-2669.34	-2466.38	-2291.82	-2139.43	-2004.92	-1221.01
NET PRESENT VALUE AT 15%	-4662.52	-4365.05	-3977.04	-3602.15	-3295.51	-3065.90	-2885.65	-2740.24	-2620.60	-2520.71	-2436.36	-2034.05
PRETAX CASH FLOW	-5000.00	366.86	550.29	611.43	611.43	611.43	611.43	611.43	611.43	611.43	611.43	611.43
NET PRESENT VALUE AT 10%	-4767.31	-4449.33	-4015.71	-3577.71	-3179.53	-2817.55	-2488.48	-2189.32	-1917.36	-1670.12	-1445.36	-64.29
NET PRESENT VALUE AT 15%	-4662.52	-4365.05	-3977.04	-3602.15	-3276.16	-2992.69	-2746.19	-2531.85	-2345.46	-2183.39	-2042.45	-1335.13
												0.06

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.141	0.160	0.092	0.053	0.035	0.024	0.017	0.012	0.009	0.006	0.055
UNIT TOTAL COSTS	0.000	0.685	0.704	0.636	0.597	0.580	0.569	0.562	0.557	0.553	0.551	0.599
UNIT PROFIT BEFORE TAX	0.000	-0.080	-0.099	-0.031	0.008	0.026	0.037	0.044	0.049	0.052	0.055	0.006
UNIT INCOME TAX		0.000	0.000	0.000	0.004	0.012	0.016	0.020	0.022	0.023	0.025	0.012
UNIT PROFIT AFTER TAX ($)		-0.080	-0.099	-0.031	0.004	0.014	0.020	0.024	0.027	0.029	0.030	-0.006

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	5000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	5000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00	5000.00
NPV OF GOVERNMENT COST ($ 000)	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52	4662.52
GOVERNMENT COST INCL TAXES*	5000.00	0.00	0.00	0.00	-36.30	-116.16	-164.34	-196.63	-218.97	-234.57	-245.52	-271.60
ACCUM GOVERNMENT COST INCL TAXES*	5000.00	5000.00	5000.00	5000.00	4963.70	4847.54	4683.20	4486.57	4267.60	4033.03	3787.51	1128.70
NPV OF GOVERNMENT COST INCL TAXES*	4662.52	4662.52	4662.52	4662.52	4644.48	4594.26	4532.48	4468.20	4405.95	4347.97	4295.20	4010.78

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

10 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $12 MILLION - FIXED AND VARIABLE COSTS $0.26/LITRE
50 PERCENT GOVERNMENT CAPITAL

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2400.00	3600.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00	4000.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3332.57	4998.86	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	3332.57	4998.86	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29	5554.29
COSTS ($ 000)												
OPERATING	0.00	1560.00	2340.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00	2600.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3445.71	5168.57	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86	5742.86
DEPRECIATION	0.00	1015.50	1728.80	1104.15	636.48	422.57	293.52	207.03	147.19	105.40	76.08	6.22
TOTAL COSTS	0.00	4461.21	6897.37	6847.01	6379.34	6165.43	6036.38	5949.88	5890.05	5848.26	5818.93	5749.07
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-1128.64	-1898.51	-1292.72	-825.05	-611.14	-482.09	-395.60	-335.77	-293.97	-264.65	-194.79
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-1128.64	-1898.51	-1292.72	-825.05	-611.14	-482.09	-395.60	-335.77	-293.97	-264.65	-194.79
CAPITAL (-)	12000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	1015.50	1728.80	1104.15	636.48	422.57	293.52	207.03	147.19	105.40	76.08	6.22
NET CASH FLOW	-6000.00	-113.14	-169.71	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57
NET PRESENT VALUE AT 10%	-5720.78	-5818.85	-5952.58	-6087.66	-6210.46	-6322.10	-6423.59	-6515.86	-6599.73	-6675.98	-6745.30	-7171.24
NET PRESENT VALUE AT 15%	-5595.03	-5686.77	-5806.44	-5922.06	-6022.60	-6110.03	-6186.05	-6252.15	-6309.64	-6359.62	-6403.09	-6621.23
PRETAX CASH FLOW	-6000.00	-113.14	-169.71	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57	-188.57
NET PRESENT VALUE AT 10%	-5720.78	-5818.85	-5952.58	-6087.66	-6210.46	-6322.10	-6423.59	-6515.86	-6599.73	-6675.98	-6745.30	-7171.24
NET PRESENT VALUE AT 15%	-5595.03	-5686.77	-5806.44	-5922.06	-6022.60	-6110.03	-6186.05	-6252.15	-6309.64	-6359.62	-6403.09	-6621.23

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260
UNIT DEPRECIATION		0.169	0.192	0.110	0.064	0.042	0.029	0.021	0.015	0.011	0.008	0.066
UNIT TOTAL COSTS	0.000	0.744	0.766	0.685	0.638	0.617	0.604	0.595	0.589	0.585	0.582	0.640
UNIT PROFIT BEFORE TAX	0.000	-0.188	-0.211	-0.129	-0.083	-0.061	-0.048	-0.040	-0.034	-0.029	-0.026	-0.085
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.188	-0.211	-0.129	-0.083	-0.061	-0.048	-0.040	-0.034	-0.029	-0.026	-0.085

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	6000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	6000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
NPV OF GOVERNMENT COST ($ 000)	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03
GOVERNMENT COST INCL TAXES*	6000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
NPV OF GOVERNMENT COST INCL TAXES*	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03	5595.03

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

10 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $15 MILLION - FIXED AND VARIABLE COSTS $0.28/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2100.00	3150.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3032.57	4548.86	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	3032.57	4548.86	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29	5054.29
COSTS ($ 000)												
OPERATING	0.00	1680.00	2520.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00	2800.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3565.71	5348.57	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86	5942.86
DEPRECIATION	0.00	1269.38	2160.99	1380.19	795.60	528.21	366.90	258.78	183.99	131.75	95.10	7.77
TOTAL COSTS	0.00	4835.09	7509.57	7323.05	6738.46	6471.07	6309.75	6201.64	6126.85	6074.61	6037.95	5950.63
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-1802.52	-2960.71	-2268.76	-1684.18	-1416.79	-1255.47	-1147.35	-1072.56	-1020.32	-983.67	-896.34
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-1802.52	-2960.71	-2268.76	-1684.18	-1416.79	-1255.47	-1147.35	-1072.56	-1020.32	-983.67	-896.34
CAPITAL (-)	15000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	1269.38	2160.99	1380.19	795.60	528.21	366.90	258.78	183.99	131.75	95.10	7.77
NET CASH FLOW	-7500.00	-533.14	-799.71	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57
NET PRESENT VALUE AT 10%	-7150.97	-7613.09	-8243.25	-8879.78	-9458.44	-9984.50	-10462.73	-10897.49	-11292.73	-11652.03	-11978.67	-13985.73
NET PRESENT VALUE AT 15%	-6993.79	-7426.10	-7989.98	-8534.80	-9008.55	-9420.51	-9778.74	-10090.24	-10361.11	-10596.65	-10801.46	-11829.39
PRETAX CASH FLOW	-7500.00	-533.14	-799.71	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57	-888.57
NET PRESENT VALUE AT 10%	-7150.97	-7613.09	-8243.25	-8879.78	-9458.44	-9984.50	-10462.73	-10897.49	-11292.73	-11652.03	-11978.67	-13985.73
NET PRESENT VALUE AT 15%	-6993.79	-7426.10	-7989.98	-8534.80	-9008.55	-9420.51	-9778.74	-10090.24	-10361.11	-10596.65	-10801.46	-11829.39
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280
UNIT DEPRECIATION		0.212	0.240	0.138	0.080	0.053	0.037	0.026	0.018	0.013	0.010	0.083
UNIT TOTAL COSTS	0.000	0.806	0.834	0.732	0.674	0.647	0.631	0.620	0.613	0.607	0.604	0.677
UNIT PROFIT BEFORE TAX	0.000	-0.300	-0.329	-0.227	-0.168	-0.142	-0.126	-0.115	-0.107	-0.102	-0.098	-0.171
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.300	-0.329	-0.227	-0.168	-0.142	-0.126	-0.115	-0.107	-0.102	-0.098	-0.171

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	7500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	7500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
NPV OF GOVERNMENT COST ($ 000)	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79
GOVERNMENT COST INCL TAXES*	7500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00	7500.00
NPV OF GOVERNMENT COST INCL TAXES*	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79	6993.79

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $35 MILLION - FIXED AND VARIABLE COSTS $0.20/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	13500.00	20250.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	18162.86	27244.29	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	18162.86	27244.29	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43
COSTS ($ 000)												
OPERATING	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	15428.57	23142.86	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29
DEPRECIATION	0.00	2961.88	5042.32	3220.45	1856.41	1232.50	856.09	603.82	429.32	307.42	221.89	18.13
TOTAL COSTS	0.00	18390.45	28185.18	28934.73	27570.69	26946.79	26570.38	26318.11	26143.60	26021.70	25936.18	25732.42
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-227.59	-940.89	1336.70	2700.73	3324.64	3701.05	3953.32	4127.83	4249.73	4335.25	4539.01
INCOME TAXES	0.00	0.00	0.00	598.84	1209.93	1489.44	1658.07	1771.09	1849.27	1903.88	1942.19	2033.48
NET INCOME	0.00	-227.59	-940.89	737.86	1490.81	1835.20	2042.98	2182.23	2278.56	2345.85	2393.06	2505.53
CAPITAL (-)	35000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	2961.88	5042.32	3220.45	1856.41	1232.50	856.09	603.82	429.32	307.42	221.89	18.13
NET CASH FLOW	-17500.00	2734.29	4101.43	3958.30	3347.21	3067.70	2899.07	2786.06	2707.88	2653.27	2614.95	2523.67
NET PRESENT VALUE AT 10%	-16685.60	-14315.56	-11083.69	-8248.16	-6068.36	-4252.20	-2691.91	-1328.76	-124.30	948.58	1909.84	7667.31
NET PRESENT VALUE AT 15%	-16318.83	-14101.67	-11209.73	-8782.74	-6998.13	-5575.89	-4407.13	-3430.44	-2604.98	-1901.66	-1298.92	1652.70
PRETAX CASH FLOW	-17500.00	2734.29	4101.43	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14	4557.14
NET PRESENT VALUE AT 10%	-16685.60	-14315.56	-11083.69	-7819.18	-4851.44	-2153.50	299.18	2520.88	4555.89	6398.62	8073.83	18367.27
NET PRESENT VALUE AT 15%	-16318.83	-14101.67	-11209.73	-8415.57	-5985.87	-3873.09	-2035.89	-438.33	950.86	2158.85	3209.28	8481.12
RATE OF RETURN ON NET CASH FLOW							0.04	0.07	0.10	0.11	0.13	0.17

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
UNIT DEPRECIATION		0.099	0.112	0.064	0.037	0.025	0.017	0.012	0.009	0.006	0.004	0.039
UNIT TOTAL COSTS	0.000	0.613	0.626	0.579	0.551	0.539	0.531	0.526	0.523	0.520	0.519	0.553
UNIT PROFIT BEFORE TAX	0.000	-0.008	-0.021	0.027	0.054	0.066	0.074	0.079	0.083	0.085	0.087	0.053
UNIT INCOME TAX		0.000	0.000	0.012	0.024	0.030	0.033	0.035	0.037	0.038	0.039	0.025
UNIT PROFIT AFTER TAX ($)		-0.008	-0.021	0.015	0.030	0.037	0.041	0.044	0.046	0.047	0.048	0.028

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	17500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	17500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00
NPV OF GOVERNMENT COST ($ 000)	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83	16318.83
GOVERNMENT COST INCL TAXES*	17500.00	0.00	0.00	-598.84	-1209.93	-1489.44	-1658.07	-1771.09	-1849.27	-1903.88	-1942.19	-2033.48
ACCUM GOVERNMENT COST INCL TAXES*	17500.00	17500.00	17500.00	16901.16	15691.23	14201.79	12543.72	10772.63	8923.37	7019.49	5077.30	-15057.36
NPV OF GOVERNMENT COST INCL TAXES*	16318.83	16318.83	16318.83	15976.45	15374.90	14730.97	14107.64	13528.67	13002.99	12532.38	12114.92	9951.29

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $55 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	12000.00	18000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	16662.86	24994.29	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	16662.86	24994.29	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43	27771.43
COSTS ($ 000)												
OPERATING	0.00	6900.00	10350.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00	11500.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	16328.57	24492.86	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29	27214.29
DEPRECIATION	0.00	4654.38	7923.64	5060.70	2917.21	1936.79	1345.29	948.87	674.64	483.08	348.69	28.49
TOTAL COSTS	0.00	20982.95	32416.50	32274.99	30131.50	29151.07	28559.58	28163.15	27888.93	27697.37	27562.97	27242.78
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-4320.09	-7422.22	-4503.56	-2360.07	-1379.65	-788.15	-391.72	-117.50	74.06	208.46	528.65
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.18	93.39	236.83
NET INCOME	0.00	-4320.09	-7422.22	-4503.56	-2360.07	-1379.65	-788.15	-391.72	-117.50	40.88	115.07	291.81
CAPITAL (-)	55000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	4654.38	7923.64	5060.70	2917.21	1936.79	1345.29	948.87	674.64	483.08	348.69	28.49
NET CASH FLOW	-27500.00	334.29	501.43	557.14	557.14	557.14	557.14	557.14	557.14	523.96	463.75	320.31
NET PRESENT VALUE AT 10%	-26220.22	-25930.47	-25535.35	-25136.24	-24773.41	-24443.57	-24143.71	-23871.12	-23623.30	-23411.43	-23240.95	-22427.65
NET PRESENT VALUE AT 15%	-25643.88	-25372.82	-25019.26	-24677.65	-24380.60	-24122.30	-23897.69	-23702.38	-23532.54	-23393.65	-23286.75	-22865.68
PRETAX CASH FLOW	-27500.00	334.29	501.43	557.14	557.14	557.14	557.14	557.14	557.14	557.14	557.14	557.14
NET PRESENT VALUE AT 10%	-26220.22	-25930.47	-25535.35	-25136.24	-24773.41	-24443.57	-24143.71	-23871.12	-23623.30	-23398.01	-23193.21	-21934.76
NET PRESENT VALUE AT 15%	-25643.88	-25372.82	-25019.26	-24677.65	-24380.60	-24122.30	-23897.69	-23702.38	-23532.54	-23384.85	-23256.43	-22611.91
RATE OF RETURN ON NET CASH FLOW												

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.155	0.176	0.101	0.058	0.039	0.027	0.019	0.013	0.010	0.007	0.061
UNIT TOTAL COSTS	0.000	0.699	0.720	0.645	0.603	0.583	0.571	0.563	0.558	0.554	0.551	0.605
UNIT PROFIT BEFORE TAX	0.000	-0.144	-0.165	-0.090	-0.047	-0.028	-0.016	-0.008	-0.002	0.001	0.004	-0.049
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000
UNIT PROFIT AFTER TAX ($)		-0.144	-0.165	-0.090	-0.047	-0.028	-0.016	-0.008	-0.002	0.001	0.002	-0.050

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	27500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	27500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00
NPV OF GOVERNMENT COST ($ 000)	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88
GOVERNMENT COST INCL TAXES*	27500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-33.18	-93.39	-236.83
ACCUM GOVERNMENT COST INCL TAXES*	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27500.00	27466.82	27373.43	25319.53
NPV OF GOVERNMENT COST INCL TAXES*	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25643.88	25635.68	25615.61	25407.24

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $75 MILLION - FIXED AND VARIABLE COSTS $0.25/LITRE
50 PERCENT GOVERNMENT CAPITAL

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	10500.00	15750.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00	17500.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	15162.86	22744.29	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	15162.86	22744.29	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43	25271.43
COSTS ($ 000)												
OPERATING	0.00	7500.00	11250.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00	12500.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	16928.57	25392.86	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29	28214.29
DEPRECIATION	0.00	6346.88	10804.97	6900.96	3978.02	2641.07	1834.49	1293.91	919.97	658.75	475.48	38.86
TOTAL COSTS	0.00	23275.45	36197.83	35115.24	32192.30	30855.36	30048.77	29508.19	29134.25	28873.03	28689.77	28253.14
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-8112.59	-13453.54	-9843.81	-6920.88	-5583.93	-4777.35	-4236.76	-3862.82	-3601.61	-3418.34	-2981.71
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-8112.59	-13453.54	-9843.81	-6920.88	-5583.93	-4777.35	-4236.76	-3862.82	-3601.61	-3418.34	-2981.71
CAPITAL (-)	75000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	6346.88	10804.97	6900.96	3978.02	2641.07	1834.49	1293.91	919.97	658.75	475.48	38.86
NET CASH FLOW	-37500.00	-1765.71	-2648.57	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86
NET PRESENT VALUE AT 10%	-35754.85	-37285.34	-39372.38	-41480.49	-43396.96	-45139.21	-46723.07	-48162.94	-49471.92	-50661.89	-51743.69	-58390.87
NET PRESENT VALUE AT 15%	-34968.93	-36400.70	-38268.23	-40072.60	-41641.63	-43005.99	-44192.40	-45224.06	-46121.15	-46901.23	-47579.56	-50983.95
PRETAX CASH FLOW	-37500.00	-1765.71	-2648.57	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86	-2942.86
NET PRESENT VALUE AT 10%	-35754.85	-37285.34	-39372.38	-41480.49	-43396.96	-45139.21	-46723.07	-48162.94	-49471.92	-50661.89	-51743.69	-58390.87
NET PRESENT VALUE AT 15%	-34968.93	-36400.70	-38268.23	-40072.60	-41641.63	-43005.99	-44192.40	-45224.06	-46121.15	-46901.23	-47579.56	-50983.95
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
UNIT DEPRECIATION		0.212	0.240	0.138	0.080	0.053	0.037	0.026	0.018	0.013	0.010	0.083
UNIT TOTAL COSTS	0.000	0.776	0.804	0.702	0.644	0.617	0.601	0.590	0.583	0.577	0.574	0.647
UNIT PROFIT BEFORE TAX	0.000	-0.270	-0.299	-0.197	-0.138	-0.112	-0.096	-0.085	-0.077	-0.072	-0.068	-0.141
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.270	-0.299	-0.197	-0.138	-0.112	-0.096	-0.085	-0.077	-0.072	-0.068	-0.141

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	37500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	37500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00
NPV OF GOVERNMENT COST ($ 000)	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93
GOVERNMENT COST INCL TAXES*	37500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00	37500.00
NPV OF GOVERNMENT COST INCL TAXES*	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93	34968.93

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $65 MILLION - FIXED AND VARIABLE COSTS $0.18/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	27000.00	40500.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	36325.71	54488.57	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	36325.71	54488.57	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86
COSTS ($ 000)												
OPERATING	0.00	10800.00	16200.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	29657.14	44485.71	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57
DEPRECIATION	0.00	5500.63	9364.31	5980.83	3447.62	2288.93	1589.89	1121.39	797.30	570.92	412.08	33.68
TOTAL COSTS	0.00	35157.77	53850.02	55409.40	52876.19	51717.50	51018.46	50549.96	50225.88	49999.49	49840.66	49462.25
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	1167.95	638.55	5133.46	7666.67	8825.35	9524.40	9992.90	10316.98	10543.37	10702.20	11080.61
INCOME TAXES	0.00	523.24	286.07	2299.79	3434.67	3953.76	4266.93	4476.82	4622.01	4723.43	4794.59	4964.11
NET INCOME	0.00	644.71	352.48	2833.67	4232.00	4871.60	5257.47	5516.08	5694.97	5819.94	5907.62	6116.50
CAPITAL (-)	65000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	5500.63	9364.31	5980.83	3447.62	2288.93	1589.89	1121.39	797.30	570.92	412.08	33.68
NET CASH FLOW	-32500.00	6145.33	9716.79	8814.50	7679.62	7160.53	6847.36	6637.47	6492.28	6390.86	6319.70	6150.17
NET PRESENT VALUE AT 10%	-30987.53	-25660.86	-18004.17	-11689.90	-6688.72	-2449.51	1235.77	4483.33	7371.08	9955.30	12278.42	26276.25
NET PRESENT VALUE AT 15%	-30306.41	-25323.32	-18471.94	-13067.44	-8972.96	-5653.20	-2892.70	-565.85	1413.24	3107.30	4564.00	11738.42
PRETAX CASH FLOW	-32500.00	6668.57	10002.86	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29	11114.29
NET PRESENT VALUE AT 10%	-30987.53	-25207.32	-17325.21	-9363.49	-2125.56	4454.38	10436.14	15874.11	20817.71	25311.90	29397.52	54501.91
NET PRESENT VALUE AT 15%	-30306.41	-24899.04	-17845.95	-11031.37	-5105.64	47.16	4527.86	8424.11	11812.16	14758.30	17320.15	30177.50
RATE OF RETURN ON NET CASH FLOW						0.07	0.11	0.14	0.16	0.18	0.19	0.22

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
UNIT DEPRECIATION		0.092	0.104	0.060	0.034	0.023	0.016	0.011	0.008	0.006	0.004	0.036
UNIT TOTAL COSTS	0.000	0.586	0.598	0.554	0.529	0.517	0.510	0.505	0.502	0.500	0.498	0.530
UNIT PROFIT BEFORE TAX	0.000	0.019	0.007	0.051	0.077	0.088	0.095	0.100	0.103	0.105	0.107	0.075
UNIT INCOME TAX		0.009	0.003	0.023	0.034	0.040	0.043	0.045	0.046	0.047	0.048	0.034
UNIT PROFIT AFTER TAX ($)		0.011	0.004	0.028	0.042	0.049	0.053	0.055	0.057	0.058	0.059	0.042

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	32500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	32500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00	32500.00
NPV OF GOVERNMENT COST ($ 000)	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41	30306.41
GOVERNMENT COST INCL TAXES*	32500.00	-523.24	-286.07	-2299.79	-3434.67	-3953.76	-4266.93	-4476.82	-4622.01	-4723.43	-4794.59	-4964.11
ACCUM GOVERNMENT COST INCL TAXES*	32500.00	31976.76	31690.69	29390.90	25956.23	22002.47	17735.54	13258.73	8636.72	3913.29	-881.30	-50150.81
NPV OF GOVERNMENT COST INCL TAXES*	30306.41	29910.76	29722.67	28407.75	26700.12	24990.80	23386.70	21923.22	20609.36	19441.80	18411.23	13111.88

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $90 MILLION - FIXED AND VARIABLE COSTS $0.21/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	24000.00	36000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	33325.71	49988.57	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	33325.71	49988.57	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86	55542.86
COSTS ($ 000)												
OPERATING	0.00	12600.00	18900.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00	21000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	31457.14	47185.71	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57	52428.57
DEPRECIATION	0.00	7616.25	12965.96	8281.15	4773.62	3169.29	2201.39	1552.69	1103.96	790.50	570.58	46.63
TOTAL COSTS	0.00	39073.39	60151.68	60709.72	57202.19	55597.86	54629.96	53981.26	53532.53	53219.07	52999.15	52475.20
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-5747.68	-10163.11	-5166.86	-1659.34	-55.00	912.90	1561.60	2010.33	2323.79	2543.71	3067.66
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	408.98	699.60	900.63	1041.06	1139.58	1374.31
NET INCOME	0.00	-5747.68	-10163.11	-5166.86	-1659.34	-55.00	503.92	862.00	1109.70	1282.73	1404.13	1693.35
CAPITAL (-)	90000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	7616.25	12965.96	8281.15	4773.62	3169.29	2201.39	1552.69	1103.96	790.50	570.58	46.63
NET CASH FLOW	-45000.00	1868.57	2802.86	3114.29	3114.29	3114.29	2705.31	2414.69	2213.66	2073.23	1974.70	1739.97
NET PRESENT VALUE AT 10%	-42905.82	-41286.17	-39077.56	-36846.64	-34818.53	-32974.79	-31518.78	-30337.33	-29352.70	-28514.37	-27788.46	-23711.35
NET PRESENT VALUE AT 15%	-41962.72	-40447.54	-38471.22	-36561.74	-34901.32	-33457.48	-32366.84	-31520.34	-30845.53	-30295.97	-29840.80	-27745.25
PRETAX CASH FLOW	-45000.00	1868.57	2802.86	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29	3114.29
NET PRESENT VALUE AT 10%	-42905.82	-41286.17	-39077.56	-36846.64	-34818.53	-32974.79	-31298.67	-29774.92	-28389.69	-27130.40	-25985.58	-18951.19
NET PRESENT VALUE AT 15%	-41962.72	-40447.54	-38471.22	-36561.74	-34901.32	-33457.48	-32201.96	-31110.21	-30160.85	-29335.33	-28617.49	-25014.78
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210	0.210
UNIT DEPRECIATION		0.127	0.144	0.083	0.048	0.032	0.022	0.016	0.011	0.008	0.006	0.050
UNIT TOTAL COSTS	0.000	0.651	0.668	0.607	0.572	0.556	0.546	0.540	0.535	0.532	0.530	0.574
UNIT PROFIT BEFORE TAX	0.000	-0.096	-0.113	-0.052	-0.017	-0.001	0.009	0.016	0.020	0.023	0.025	-0.018
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.004	0.007	0.009	0.010	0.011	0.004
UNIT PROFIT AFTER TAX ($)		-0.096	-0.113	-0.052	-0.017	-0.001	0.005	0.009	0.011	0.013	0.014	-0.023

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	45000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	45000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
NPV OF GOVERNMENT COST ($ 000)	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72
GOVERNMENT COST INCL TAXES*	45000.00	0.00	0.00	0.00	0.00	0.00	-408.98	-699.60	-900.63	-1041.06	-1139.58	-1374.31
ACCUM GOVERNMENT COST INCL TAXES*	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	44591.02	43891.43	42990.80	41949.74	40810.16	27581.60
NPV OF GOVERNMENT COST INCL TAXES*	41962.72	41962.72	41962.72	41962.72	41962.72	41962.72	41808.97	41580.27	41324.25	41066.92	40821.97	39416.54

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $115 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	21000.00	31500.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00	35000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	30325.71	45488.57	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	30325.71	45488.57	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86	50542.86
COSTS ($ 000)												
OPERATING	0.00	13800.00	20700.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00	23000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	32657.14	48985.71	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57	54428.57
DEPRECIATION	0.00	9731.88	16567.62	10581.47	6099.63	4049.65	2812.88	1983.99	1410.62	1010.08	729.07	59.58
TOTAL COSTS	0.00	42389.02	65553.33	65010.04	60528.20	58478.22	57241.45	56412.56	55839.19	55438.65	55157.64	54488.15
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-12063.30	-20064.76	-14467.18	-9985.34	-7935.36	-6698.60	-5869.71	-5296.33	-4895.80	-4614.79	-3945.29
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-12063.30	-20064.76	-14467.18	-9985.34	-7935.36	-6698.60	-5869.71	-5296.33	-4895.80	-4614.79	-3945.29
CAPITAL (-)	115000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	9731.88	16567.62	10581.47	6099.63	4049.65	2812.88	1983.99	1410.62	1010.08	729.07	59.58
NET CASH FLOW	-57500.00	-2331.43	-3497.14	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71
NET PRESENT VALUE AT 10%	-54824.10	-56844.94	-59600.64	-62384.18	-64914.66	-67215.10	-69306.41	-71207.60	-72935.96	-74507.19	-75935.58	-84712.44
NET PRESENT VALUE AT 15%	-53619.03	-55509.52	-57975.38	-60357.86	-62429.58	-64231.07	-65797.59	-67159.77	-68344.29	-69374.29	-70269.96	-74765.07
PRETAX CASH FLOW	-57500.00	-2331.43	-3497.14	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71	-3885.71
NET PRESENT VALUE AT 10%	-54824.10	-56844.94	-59600.64	-62384.18	-64914.66	-67215.10	-69306.41	-71207.60	-72935.96	-74507.19	-75935.58	-84712.44
NET PRESENT VALUE AT 15%	-53619.03	-55509.52	-57975.38	-60357.86	-62429.58	-64231.07	-65797.59	-67159.77	-68344.29	-69374.29	-70269.96	-74765.07
RATE OF RETURN ON NET CASH FLOW												

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.162	0.184	0.106	0.061	0.040	0.028	0.020	0.014	0.010	0.007	0.063
UNIT TOTAL COSTS	0.000	0.706	0.728	0.650	0.605	0.585	0.572	0.564	0.558	0.554	0.552	0.608
UNIT PROFIT BEFORE TAX	0.000	-0.201	-0.223	-0.145	-0.100	-0.079	-0.067	-0.059	-0.053	-0.049	-0.046	-0.102
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.201	-0.223	-0.145	-0.100	-0.079	-0.067	-0.059	-0.053	-0.049	-0.046	-0.102

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	57500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	57500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00
NPV OF GOVERNMENT COST ($ 000)	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03
GOVERNMENT COST INCL TAXES*	57500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00	57500.00
NPV OF GOVERNMENT COST INCL TAXES*	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03	53619.03

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $120 MILLION - FIXED AND VARIABLE COSTS $0.17/LITRE
50 PERCENT GOVERNMENT CAPITAL

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	54000.00	81000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	72651.43	108977.14	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	72651.43	108977.14	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71
COSTS ($ 000)												
OPERATING	0.00	20400.00	30600.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	58114.29	87171.43	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14
DEPRECIATION	0.00	10155.00	17287.95	11041.53	6364.83	4225.72	2935.18	2070.25	1471.95	1054.00	760.77	62.17
TOTAL COSTS	0.00	68269.29	104459.38	107898.67	103221.97	101082.86	99792.32	98927.40	98329.09	97911.14	97617.91	96919.31
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	4382.14	4517.76	13187.04	17863.74	20002.85	21293.39	22158.32	22756.62	23174.57	23467.80	24166.40
INCOME TAXES	0.00	1963.20	2023.96	5907.79	8002.96	8961.28	9539.44	9926.93	10194.97	10382.21	10513.58	10826.55
NET INCOME	0.00	2418.94	2493.81	7279.25	9860.79	11041.57	11753.95	12231.39	12561.66	12792.36	12954.23	13339.85
CAPITAL (-)	120000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	10155.00	17287.95	11041.53	6364.83	4225.72	2935.18	2070.25	1471.95	1054.00	760.77	62.17
NET CASH FLOW	-60000.00	12573.94	19781.76	18320.78	16225.62	15267.29	14689.13	14301.64	14033.60	13846.36	13715.00	13402.02
NET PRESENT VALUE AT 10%	-57207.76	-46308.86	-30721.12	-17597.02	-7030.45	2008.17	9913.93	16911.40	23153.51	28752.44	33794.09	64261.84
NET PRESENT VALUE AT 15%	-55950.29	-45754.41	-31806.14	-20572.99	-11922.10	-4843.88	1078.00	6091.63	10369.60	14039.94	17201.26	32815.38
PRETAX CASH FLOW	-60000.00	14537.14	21805.71	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57	24228.57
NET PRESENT VALUE AT 10%	-57207.76	-44607.19	-27424.60	-10068.45	5709.87	20053.79	33093.73	44948.21	55725.02	65522.11	74428.56	129154.84
NET PRESENT VALUE AT 15%	-55950.29	-44162.50	-28787.13	-13931.69	-1013.92	10218.92	19986.61	28480.25	35866.03	42288.44	47873.15	75901.51

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605	0.605
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
UNIT DEPRECIATION		0.085	0.096	0.055	0.032	0.021	0.015	0.010	0.007	0.005	0.004	0.033
UNIT TOTAL COSTS	0.000	0.569	0.580	0.539	0.516	0.505	0.499	0.495	0.492	0.490	0.488	0.517
UNIT PROFIT BEFORE TAX	0.000	0.037	0.025	0.066	0.089	0.100	0.106	0.111	0.114	0.116	0.117	0.088
UNIT INCOME TAX		0.016	0.011	0.030	0.040	0.045	0.048	0.050	0.051	0.052	0.053	0.039
UNIT PROFIT AFTER TAX ($)		0.020	0.014	0.036	0.049	0.055	0.059	0.061	0.063	0.064	0.065	0.049

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	60000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	60000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00
NPV OF GOVERNMENT COST ($ 000)	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29	55950.29
GOVERNMENT COST INCL TAXES*	60000.00	-1963.20	-2023.96	-5907.79	-8002.96	-8961.28	-9539.44	-9926.93	-10194.97	-10382.21	-10513.58	-10826.55
ACCUM GOVERNMENT COST INCL TAXES*	60000.00	58036.80	56012.84	50105.05	42102.09	33140.81	23601.37	13674.45	3479.48	-6902.73	-17416.30	-124995.72
NPV OF GOVERNMENT COST INCL TAXES*	55950.29	54465.83	53135.04	49757.24	45778.36	41904.15	38317.92	35072.79	32174.75	29608.42	27348.60	15772.27

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $160 MILLION - FIXED AND VARIABLE COSTS $0.20/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	48000.00	72000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	66651.43	99977.14	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	66651.43	99977.14	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71
COSTS ($ 000)												
OPERATING	0.00	24000.00	36000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	61714.29	92571.43	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14
DEPRECIATION	0.00	13540.00	23050.60	14722.04	8486.44	5634.29	3913.58	2760.34	1962.60	1405.33	1014.36	82.89
TOTAL COSTS	0.00	75254.29	115622.03	117579.18	111343.58	108491.44	106770.72	105617.48	104819.74	104262.47	103871.50	102940.04
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-8602.86	-15644.89	-6493.47	-257.87	2594.28	4315.00	5468.24	6265.98	6823.24	7214.21	8145.68
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	1162.24	1933.12	2449.77	2807.16	3056.81	3231.97	3649.26
NET INCOME	0.00	-8602.86	-15644.89	-6493.47	-257.87	1432.04	2381.88	3018.47	3458.82	3766.43	3982.24	4496.41
CAPITAL (-)	160000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	13540.00	23050.60	14722.04	8486.44	5634.29	3913.58	2760.34	1962.60	1405.33	1014.36	82.89
NET CASH FLOW	-80000.00	4937.14	7405.71	8228.57	8228.57	7066.33	6295.45	5778.80	5421.41	5171.76	4996.60	4579.31
NET PRESENT VALUE AT 10%	-76277.01	-71997.57	-66161.97	-60267.43	-54908.76	-50725.31	-47337.07	-44509.63	-42098.20	-40006.94	-38170.18	-27565.43
NET PRESENT VALUE AT 15%	-74600.38	-70596.99	-65375.16	-60329.92	-55942.75	-52666.66	-50128.66	-48102.83	-46450.18	-45079.27	-43927.55	-38483.06
PRETAX CASH FLOW	-80000.00	4937.14	7405.71	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57	8228.57
NET PRESENT VALUE AT 10%	-76277.01	-71997.57	-66161.97	-60267.43	-54908.76	-50037.24	-45608.58	-41582.53	-37922.48	-34595.17	-31570.33	-12984.05
NET PRESENT VALUE AT 15%	-74600.38	-70596.99	-65375.16	-60329.92	-55942.75	-52127.82	-48810.49	-45925.86	-43417.48	-41236.29	-39339.59	-29820.53
RATE OF RETURN ON NET CASH FLOW												0.04

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
UNIT DEPRECIATION		0.113	0.128	0.074	0.042	0.028	0.020	0.014	0.010	0.007	0.005	0.044
UNIT TOTAL COSTS	0.000	0.627	0.642	0.588	0.557	0.542	0.534	0.528	0.524	0.521	0.519	0.558
UNIT PROFIT BEFORE TAX	0.000	-0.072	-0.087	-0.032	-0.001	0.013	0.022	0.027	0.031	0.034	0.036	-0.003
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.006	0.010	0.012	0.014	0.015	0.016	0.007
UNIT PROFIT AFTER TAX ($)		-0.072	-0.087	-0.032	-0.001	0.007	0.012	0.015	0.017	0.019	0.020	-0.010

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	80000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	80000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00
NPV OF GOVERNMENT COST ($ 000)	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38	74600.38
GOVERNMENT COST INCL TAXES*	80000.00	0.00	0.00	0.00	0.00	-1162.24	-1933.12	-2449.77	-2807.16	-3056.81	-3231.97	-3649.26
ACCUM GOVERNMENT COST INCL TAXES*	80000.00	80000.00	80000.00	80000.00	80000.00	78837.76	76904.65	74454.88	71647.72	68590.91	65358.94	29781.06
NPV OF GOVERNMENT COST INCL TAXES*	74600.38	74600.38	74600.38	74600.38	74600.38	74097.92	73371.19	72570.35	71772.38	71016.79	70322.10	66522.53

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - PESSIMISTIC CASE
ETHANOL $0.35/LITRE - CAPITAL $200 MILLION - FIXED AND VARIABLE COSTS $0.22/LITRE
50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714 29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	42000.00	63000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00	70000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	60651.43	90977.14	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	60651.43	90977.14	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71	101085.71
COSTS ($ 000)												
OPERATING	0.00	26400.00	39600.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00	44000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	64114.29	96171.43	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14	106857.14
DEPRECIATION	0.00	16925.00	28813.25	18402.55	10608.05	7042.87	4891.97	3450.42	2453.24	1756.66	1267.95	103.62
TOTAL COSTS	0.00	81039.29	124984.68	125259.69	117465.19	113900.01	111749.11	110307.56	109310.39	108613.81	108125.09	106960.76
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-20387.86	-34007.54	-24173.98	-16379.48	-12814.29	-10663.40	-9221.85	-8224.67	-7528.09	-7039.38	-5875.04
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NET INCOME	0.00	-20387.86	-34007.54	-24173.98	-16379.48	-12814.29	-10663.40	-9221.85	-8224.67	-7528.09	-7039.38	-5875.04
CAPITAL (-)	200000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	16925.00	28813.25	18402.55	10608.05	7042.87	4891.97	3450.42	2453.24	1756.66	1267.95	103.62
NET CASH FLOW	-100000.00	-3462.86	-5194.29	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43
NET PRESENT VALUE AT 10%	-95346.26	-98347.81	-102440.83	-106575.20	-110333.71	-113750.54	-116856.75	-119680.58	-122247.70	-124581.44	-126703.02	-139739.23
NET PRESENT VALUE AT 15%	-93250.48	-96058.42	-99720.95	-103259.63	-106336.74	-109012.49	-111339.22	-113362.47	-115121.82	-116651.69	-117982.01	-124658.57
PRETAX CASH FLOW	-100000.00	-3462.86	-5194.29	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43	-5771.43
NET PRESENT VALUE AT 10%	-95346.26	-98347.81	-102440.83	-106575.20	-110333.71	-113750.54	-116856.75	-119680.58	-122247.70	-124581.44	-126703.02	-139739.23
NET PRESENT VALUE AT 15%	-93250.48	-96058.42	-99720.95	-103259.63	-106336.74	-109012.49	-111339.22	-113362.47	-115121.82	-116651.69	-117982.01	-124658.57

RATE OF RETURN ON NET CASH FLOW

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505	0.505
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220
UNIT DEPRECIATION		0.141	0.160	0.092	0.053	0.035	0.024	0.017	0.012	0.009	0.006	0.055
UNIT TOTAL COSTS	0.000	0.675	0.694	0.626	0.587	0.570	0.559	0.552	0.547	0.543	0.541	0.589
UNIT PROFIT BEFORE TAX	0.000	-0.170	-0.189	-0.121	-0.082	-0.064	-0.053	-0.046	-0.041	-0.038	-0.035	-0.084
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT PROFIT AFTER TAX ($)		-0.170	-0.189	-0.121	-0.082	-0.064	-0.053	-0.046	-0.041	-0.038	-0.035	-0.084

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	100000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	100000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
NPV OF GOVERNMENT COST ($ 000)	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48
GOVERNMENT COST INCL TAXES*	100000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST INCL TAXES*	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
NPV OF GOVERNMENT COST INCL TAXES*	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48	93250.48

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

C2 SUBSIDY EQUIVALENT TO 50% GOVERNMENT CAPITAL INVESTMENT CASES

ETHANOL PLANT MODEL

SENSITIVITY

SUBSIDY ASSISTANCE TO ACHIEVE SAME RATE OF RETURN AS 50 PERCENT GOVERNMENT CAPITAL

ETHANOL PRICE $0.30, $0.35, AND $0.45/LITRE

10 MM LITRES PER YEAR WITH OPERATING COSTS $0.23, $0.26, AND $0.28/LITRE
50 MM LITRES PER YEAR WITH OPERATING COSTS $0.20, $0.23, AND $0.25/LITRE
100 MM LITRES PER YEAR WITH OPERATING COSTS $0.18, $0.21, AND $0.23/LITRE
200 MM LITRES PER YEAR WITH OPERATING COSTS $0.17, $0.20, AND $0.22/LITRE

CAPITAL COSTS OF $10, 12, AND 15 MILLION ON 10 MM LITRES
CAPITAL COSTS OF $35, 55, AND 75 MILLION ON 50 MM LITRES
CAPITAL COSTS OF $65, 90, AND 115 MILLION ON 100 MM LITRES
CAPITAL COSTS OF $120, 160, AND 200 MILLION ON 200 MM LITRES

DDG SOLD AT $170/TONNE
CO2 NOT SOLD
FEEDSTOCK AT $110/TONNE
ETHANOL YIELD OF 350 LITRES/TONNE

100%EQUITY
0% SALVAGE

NO INFLATION

FEDERAL TAX AT 28.8%
PROVINCIAL TAX AT 16%
TOTAL TAX AT 44.8%

NO GOVERNMENT CAPITAL

TUESDAY, OCTOBER 25, 1988.

10 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $10 MILLION - FIXED AND VARIABLE COSTS $0.23/LITRE
SUBSIDY TO ACHIEVE SAME RATE OF RETURN AS 50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	17142.86	25714.29	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ANIMAL FEED (TONNES)	0.00	5485.71	8228.57	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86	9142.86
CARBON DIOXIDE (TONNES)	0.00	4851.43	7277.14	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71	8085.71
SALES ($ 000)												
ETHANOL	0.00	2700.00	4050.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00
ANIMAL FEED	0.00	932.57	1398.86	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29	1554.29
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	3632.57	5448.86	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29	6054.29
GOVERNMENT SUBSIDY	0.00	366.60	549.90	611.00	611.00	611.00	611.00	611.00	611.00	611.00	611.00	611.00
TOTAL REVENUE	0.00	3999.17	5998.76	6665.29	6665.29	6665.29	6665.29	6665.29	6665.29	6665.29	6665.29	6665.29
COSTS ($ 000)												
OPERATING	0.00	1380.00	2070.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00	2300.00
FEEDSTOCK	0.00	1885.71	2828.57	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86	3142.86
TOTAL COST OF SALES	0.00	3265.71	4898.57	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86	5442.86
DEPRECIATION	0.00	1692.50	2881.33	1840.25	1060.80	704.29	489.20	345.04	245.32	175.67	126.79	10.36
TOTAL COSTS	0.00	4958.21	7779.90	7283.11	6503.66	6147.14	5932.05	5787.90	5688.18	5618.52	5569.65	5453.22
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-959.04	-1781.14	-617.83	161.62	518.14	733.23	877.39	977.10	1046.76	1095.63	1212.07
INCOME TAXES	0.00	0.00	0.00	0.00	72.41	232.13	328.49	393.07	437.74	468.95	490.84	543.01
NET INCOME	0.00	-959.04	-1781.14	-617.83	89.22	286.01	404.74	484.32	539.36	577.81	604.79	669.06
CAPITAL (-)	10000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	1692.50	2881.33	1840.25	1060.80	704.29	489.20	345.04	245.32	175.67	126.79	10.36
NET CASH FLOW	-10000.00	733.46	1100.19	1222.43	1150.02	990.30	893.94	829.36	784.69	753.48	731.58	679.42
NET PRESENT VALUE AT 10%	-9534.63	-8898.88	-8031.95	-7156.26	-6407.33	-5821.05	-5339.93	-4934.14	-4585.11	-4280.44	-4011.50	-2444.20
NET PRESENT VALUE AT 15%	-9325.05	-8730.31	-7954.56	-7205.04	-6591.89	-6132.77	-5772.38	-5481.64	-5242.44	-5042.71	-4874.08	-4069.72
PRETAX CASH FLOW	-10000.00	733.46	1100.19	1222.43	1222.43	1222.43	1222.43	1222.43	1222.43	1222.43	1222.43	1222.43
NET PRESENT VALUE AT 10%	-9534.63	-8898.88	-8031.95	-7156.26	-6360.18	-5636.47	-4978.55	-4380.45	-3836.71	-3342.41	-2893.05	-131.89
NET PRESENT VALUE AT 15%	-9325.05	-8730.31	-7954.56	-7205.04	-6553.29	-5986.55	-5493.73	-5065.19	-4692.55	-4368.51	-4086.74	-2672.60
RATE OF RETURN ON NET CASH FLOW													0.06

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667	0.667
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230	0.230
UNIT DEPRECIATION		0.282	0.320	0.184	0.106	0.070	0.049	0.035	0.025	0.018	0.013	0.110
UNIT TOTAL COSTS	0.000	0.826	0.864	0.728	0.650	0.615	0.593	0.579	0.569	0.562	0.557	0.654
UNIT PROFIT BEFORE TAX	0.000	-0.160	-0.198	-0.062	0.016	0.052	0.073	0.088	0.098	0.105	0.110	0.012
UNIT INCOME TAX		0.000	0.000	0.000	0.007	0.023	0.033	0.039	0.044	0.047	0.049	0.024
UNIT PROFIT AFTER TAX ($)		-0.160	-0.198	-0.062	0.009	0.029	0.040	0.048	0.054	0.058	0.060	-0.012

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	366.60	549.90	611.00	611.00	611.00	611.00	611.00	611.00	611.00	611.00	611.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	366.60	549.90	611.00	611.00	611.00	611.00	611.00	611.00	611.00	611.00	611.00
ACCUM GOVERNMENT COST ($ 000)	0.00	366.60	916.50	1527.50	2138.50	2749.50	3360.50	3971.50	4582.50	5193.50	5804.50	11914.50
NPV OF GOVERNMENT COST ($ 000)	0.00	297.27	685.00	1059.63	1385.39	1668.67	1914.99	2129.18	2315.44	2477.40	2618.24	3325.06
GOVERNMENT COST INCL TAXES*	0.00	366.60	549.90	611.00	538.59	378.87	282.51	217.93	173.26	142.05	120.16	67.99
ACCUM GOVERNMENT COST INCL TAXES*	0.00	366.60	916.50	1527.50	2066.09	2444.97	2727.48	2945.41	3118.67	3260.72	3380.87	4175.16
NPV OF GOVERNMENT COST INCL TAXES*	0.00	297.27	685.00	1059.63	1349.39	1532.31	1655.14	1740.84	1802.66	1848.71	1884.04	2022.23

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

50 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $35 MILLION - FIXED AND VARIABLE COSTS $0.20/LITRE
SUBSIDY TO ACHIEVE SAME RATE OF RETURN AS 50 PERCENT GOVERNMENT CAPITAL

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	85714.29	128571.43	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14	142857.14
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ANIMAL FEED (TONNES)	0.00	27428.57	41142.86	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29	45714.29
CARBON DIOXIDE (TONNES)	0.00	24257.14	36385.71	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57	40428.57
SALES ($ 000)												
ETHANOL	0.00	13500.00	20250.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00	22500.00
ANIMAL FEED	0.00	4662.86	6994.29	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43	7771.43
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	18162.86	27244.29	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43	30271.43
GOVERNMENT SUBSIDY	0.00	2733.00	4099.50	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00
TOTAL REVENUE	0.00	20895.86	31343.79	34826.43	34826.43	34826.43	34826.43	34826.43	34826.43	34826.43	34826.43	34826.43
COSTS ($ 000)												
OPERATING	0.00	6000.00	9000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
FEEDSTOCK	0.00	9428.57	14142.86	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29	15714.29
TOTAL COST OF SALES	0.00	15428.57	23142.86	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29	25714.29
DEPRECIATION	0.00	5923.75	10084.64	6440.89	3712.82	2465.00	1712.19	1207.65	858.64	614.83	443.78	36.27
TOTAL COSTS	0.00	21352.32	33227.49	32155.18	29427.10	28179.29	27426.48	26921.93	26572.92	26329.12	26158.07	25750.55
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-456.46	-1883.71	2671.25	5399.33	6647.14	7399.95	7904.50	8253.51	8497.31	8668.36	9075.88
INCOME TAXES	0.00	0.00	0.00	1196.72	2418.90	2977.92	3315.18	3541.21	3697.57	3806.80	3883.43	4065.99
NET INCOME	0.00	-456.46	-1883.71	1474.53	2980.43	3669.22	4084.77	4363.28	4555.94	4690.52	4784.93	5009.88
CAPITAL (-)	35000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	5923.75	10084.64	6440.89	3712.82	2465.00	1712.19	1207.65	858.64	614.83	443.78	36.27
NET CASH FLOW	-35000.00	5467.29	8200.93	7915.42	6693.24	6134.22	5796.96	5570.93	5414.57	5305.35	5228.72	5046.15
NET PRESENT VALUE AT 10%	-33371.19	-28632.23	-22170.02	-16499.80	-12140.98	-8509.36	-5389.41	-2663.68	-255.29	1889.98	3812.07	15324.35
NET PRESENT VALUE AT 15%	-32637.67	-28204.39	-22421.85	-17568.61	-14000.03	-11156.08	-8819.05	-6866.08	-5215.52	-3809.20	-2603.98	3297.88
PRETAX CASH FLOW	-35000.00	5467.29	8200.93	9112.14	9112.14	9112.14	9112.14	9112.14	9112.14	9112.14	9112.14	9112.14
NET PRESENT VALUE AT 10%	-33371.19	-28632.23	-22170.02	-15642.53	-9708.45	-4313.83	590.37	5048.73	9101.79	12786.38	16136.02	36718.07
NET PRESENT VALUE AT 15%	-32637.67	-28204.39	-22421.85	-16834.86	-11976.61	-7752.04	-4078.50	-884.12	1893.60	4309.02	6409.37	16950.58
RATE OF RETURN ON NET CASH FLOW							0.04	0.07	0.10	0.11	0.13	0.17

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
UNIT DEPRECIATION		0.197	0.224	0.129	0.074	0.049	0.034	0.024	0.017	0.012	0.009	0.077
UNIT TOTAL COSTS	0.000	0.712	0.738	0.643	0.589	0.564	0.549	0.538	0.531	0.527	0.523	0.591
UNIT PROFIT BEFORE TAX	0.000	-0.015	-0.042	0.053	0.108	0.133	0.148	0.158	0.165	0.170	0.173	0.105
UNIT INCOME TAX		0.000	0.000	0.024	0.048	0.060	0.066	0.071	0.074	0.076	0.078	0.050
UNIT PROFIT AFTER TAX ($)		-0.015	-0.042	0.029	0.060	0.073	0.082	0.087	0.091	0.094	0.096	0.055

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	30000.00	45000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00	50000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	2733.00	4099.50	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	2733.00	4099.50	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00	4555.00
ACCUM GOVERNMENT COST ($ 000)	0.00	2733.00	6832.50	11387.50	15942.50	20497.50	25052.50	29607.50	34162.50	38717.50	43272.50	88822.50
NPV OF GOVERNMENT COST ($ 000)	0.00	2216.12	5106.71	7899.55	10328.10	12439.89	14276.23	15873.04	17261.58	18469.00	19518.93	24788.29
GOVERNMENT COST INCL TAXES*	0.00	2733.00	4099.50	3358.28	2136.10	1577.08	1239.82	1013.79	857.43	748.20	671.57	489.01
ACCUM GOVERNMENT COST INCL TAXES*	0.00	2733.00	6832.50	10190.78	12326.88	13903.96	15143.78	16157.57	17015.00	17763.20	18434.78	23725.05
NPV OF GOVERNMENT COST INCL TAXES*	0.00	2216.12	5106.71	7215.32	8441.25	9265.60	9855.64	10294.83	10632.28	10898.72	11113.94	12057.08

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

100 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $65 MILLION - FIXED AND VARIABLE COSTS $0.18/LITRE
SUBSIDY TO ACHIEVE SAME RATE OF RETURN AS 50 PERCENT GOVERNMENT CAPITAL

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (TONNES)	0.00	171428.57	257142.86	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29	285714.29
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ANIMAL FEED (TONNES)	0.00	54857.14	82285.71	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57	91428.57
CARBON DIOXIDE (TONNES)	0.00	48514.29	72771.43	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14	80857.14
SALES ($ 000)												
ETHANOL	0.00	27000.00	40500.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
ANIMAL FEED	0.00	9325.71	13988.57	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86	15542.86
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	36325.71	54488.57	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86	60542.86
GOVERNMENT SUBSIDY	0.00	6666.00	9999.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00
TOTAL REVENUE	0.00	42991.71	64487.57	71652.86	71652.86	71652.86	71652.86	71652.86	71652.86	71652.86	71652.86	71652.86
COSTS ($ 000)												
OPERATING	0.00	10800.00	16200.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00	18000.00
FEEDSTOCK	0.00	18857.14	28285.71	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57	31428.57
TOTAL COST OF SALES	0.00	29657.14	44485.71	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57	49428.57
DEPRECIATION	0.00	11001.25	18728.61	11961.66	6895.23	4577.86	3179.78	2242.77	1594.61	1141.83	824.17	67.35
TOTAL COSTS	0.00	40658.39	63214.33	61390.23	56323.80	54006.43	52608.35	51671.34	51023.18	50570.40	50252.74	49495.92
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	2333.32	1273.24	10262.63	15329.05	17646.42	19044.51	19981.51	20629.68	21082.45	21400.12	22156.94
INCOME TAXES	0.00	1045.33	570.41	4597.66	6867.42	7905.60	8531.94	8951.72	9242.10	9444.94	9587.25	9926.31
NET INCOME	0.00	1287.99	702.83	5664.97	8461.64	9740.83	10512.57	11029.79	11387.58	11637.51	11812.87	12230.63
CAPITAL (-)	65000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	11001.25	18728.61	11961.66	6895.23	4577.86	3179.78	2242.77	1594.61	1141.83	824.17	67.35
NET CASH FLOW	-65000.00	12289.24	19431.44	17626.63	15356.87	14318.69	13692.35	13272.57	12982.19	12779.35	12637.03	12297.98
NET PRESENT VALUE AT 10%	-61975.07	-51322.95	-36011.25	-23384.40	-13383.58	-4906.56	2462.73	8956.69	14731.13	19898.61	24543.99	52534.31
NET PRESENT VALUE AT 15%	-60612.81	-50647.79	-36946.53	-26138.99	-17951.28	-11312.86	-5792.82	-1139.95	2817.51	6205.01	9117.86	23463.97
PRETAX CASH FLOW	-65000.00	13334.57	20001.86	22224.29	22224.29	22224.29	22224.29	22224.29	22224.29	22224.29	22224.29	22224.29
NET PRESENT VALUE AT 10%	-61975.07	-50416.87	-34655.70	-18735.32	-4262.25	8895.09	20856.31	31730.14	41615.45	50602.08	58771.76	108970.85
NET PRESENT VALUE AT 15%	-60612.81	-49800.16	-35696.70	-22070.16	-10221.01	82.61	9042.28	16833.29	23608.09	29499.21	34621.93	60331.67
RATE OF RETURN ON NET CASH FLOW						0.07	0.11	0.14	0.16	0.18	0.19	0.22

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
UNIT DEPRECIATION		0.183	0.208	0.120	0.069	0.046	0.032	0.022	0.016	0.011	0.008	0.072
UNIT TOTAL COSTS	0.000	0.678	0.702	0.614	0.563	0.540	0.526	0.517	0.510	0.506	0.503	0.566
UNIT PROFIT BEFORE TAX	0.000	0.039	0.014	0.103	0.153	0.176	0.190	0.200	0.206	0.211	0.214	0.151
UNIT INCOME TAX		0.017	0.006	0.046	0.069	0.079	0.085	0.090	0.092	0.094	0.096	0.068
UNIT PROFIT AFTER TAX ($)		0.021	0.008	0.057	0.085	0.097	0.105	0.110	0.114	0.116	0.118	0.083

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	60000.00	90000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00	100000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	6666.00	9999.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	6666.00	9999.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00	11110.00
ACCUM GOVERNMENT COST ($ 000)	0.00	6666.00	16665.00	27775.00	38885.00	49995.00	61105.00	72215.00	83325.00	94435.00	105545.00	216645.00
NPV OF GOVERNMENT COST ($ 000)	0.00	5405.28	12455.66	19267.61	25191.04	30341.86	34820.83	38715.59	42102.33	45047.32	47608.19	60460.58
GOVERNMENT COST INCL TAXES*	0.00	5620.67	9428.59	6512.34	4242.58	3204.40	2578.06	2158.28	1867.90	1665.06	1522.75	1183.69
ACCUM GOVERNMENT COST INCL TAXES*	0.00	5620.67	15049.26	21561.60	25804.18	29008.59	31586.65	33744.93	35612.84	37277.90	38800.64	51380.81
NPV OF GOVERNMENT COST INCL TAXES*	0.00	4614.87	11290.18	15473.41	17982.53	19715.53	20987.03	21955.45	22715.02	23325.37	23825.52	26081.28

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - OPTIMISTIC CASE
ETHANOL $0.45/LITRE - CAPITAL $120 MILLION - FIXED AND VARIABLE COSTS $0.17/LITRE
SUBSIDY TO ACHIEVE SAME RATE OF RETURN AS 50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	54000.00	81000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00	90000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	72651.43	108977.14	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71	121085.71
GOVERNMENT SUBSIDY	0.00	14532.00	21798.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00
TOTAL REVENUE	0.00	87183.43	130775.14	145305.71	145305.71	145305.71	145305.71	145305.71	145305.71	145305.71	145305.71	145305.71
COSTS ($ 000)												
OPERATING	0.00	20400.00	30600.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00	34000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	58114.29	87171.43	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14	96857.14
DEPRECIATION	0.00	20310.00	34575.90	22083.06	12729.66	8451.44	5870.36	4140.50	2943.89	2108.00	1521.54	124.34
TOTAL COSTS	0.00	78424.29	121747.33	118940.20	109586.80	105308.58	102727.51	100997.65	99801.04	98965.14	98378.68	96981.48
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	8759.14	9027.81	26365.51	35718.91	39997.13	42578.21	44308.07	45504.68	46340.58	46927.03	48324.23
INCOME TAXES	0.00	3924.10	4044.46	11811.75	16002.07	17918.72	19075.04	19850.01	20386.10	20760.58	21023.31	21649.26
NET INCOME	0.00	4835.05	4983.35	14553.76	19716.84	22078.42	23503.17	24458.05	25118.58	25580.00	25903.72	26674.98
CAPITAL (-)	120000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	20310.00	34575.90	22083.06	12729.66	8451.44	5870.36	4140.50	2943.89	2108.00	1521.54	124.34
NET CASH FLOW	-120000.00	25145.05	39559.25	36636.82	32446.50	30529.86	29373.53	28598.56	28062.48	27687.99	27425.26	26799.32
NET PRESENT VALUE AT 10%	-114415.51	-92620.18	-61448.06	-35203.25	-14073.19	4001.26	19810.23	33802.85	46284.96	57480.91	67562.47	128487.28
NET PRESENT VALUE AT 15%	-111900.58	-91511.12	-63617.59	-41154.20	-23854.93	-9700.69	2141.18	12166.78	20721.27	28060.69	34382.24	65605.01
PRETAX CASH FLOW	-120000.00	29069.14	43603.71	48448.57	48448.57	48448.57	48448.57	48448.57	48448.57	48448.57	48448.57	48448.57
NET PRESENT VALUE AT 10%	-114415.51	-89218.84	-54859.74	-20153.58	11397.48	40080.26	66155.51	89860.28	111410.08	131000.80	148810.55	258243.74
NET PRESENT VALUE AT 15%	-111900.58	-88329.17	-57583.86	-27878.25	-2047.28	20414.43	39946.36	56930.64	71699.58	84542.13	95709.58	151756.38
RATE OF RETURN ON NET CASH FLOW					0.04	0.11	0.16	0.19	0.21	0.22	0.23	0.24

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450	0.450
UNIT GOVERNMENT SUBSIDY	0.000	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.727	0.727	0.727	0.727	0.727	0.727	0.727	0.727	0.727	0.727	0.727
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
UNIT DEPRECIATION		0.169	0.192	0.110	0.064	0.042	0.029	0.021	0.015	0.011	0.008	0.066
UNIT TOTAL COSTS	0.000	0.654	0.676	0.595	0.548	0.527	0.514	0.505	0.499	0.495	0.492	0.550
UNIT PROFIT BEFORE TAX	0.000	0.073	0.050	0.132	0.179	0.200	0.213	0.222	0.228	0.232	0.235	0.176
UNIT INCOME TAX		0.033	0.022	0.059	0.080	0.090	0.095	0.099	0.102	0.104	0.105	0.079
UNIT PROFIT AFTER TAX ($)		0.040	0.028	0.073	0.099	0.110	0.118	0.122	0.126	0.128	0.130	0.097

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	14532.00	21798.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	14532.00	21798.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00	24220.00
ACCUM GOVERNMENT COST ($ 000)	0.00	14532.00	36330.00	60550.00	84770.00	108990.00	133210.00	157430.00	181650.00	205870.00	230090.00	472290.00
NPV OF GOVERNMENT COST ($ 000)	0.00	11783.62	27153.55	42003.73	54916.93	66145.80	75910.03	84400.67	91783.84	98203.98	103786.71	131805.15
GOVERNMENT COST INCL TAXES*	0.00	10607.90	17753.54	12408.25	8217.93	6301.28	5144.96	4369.99	3833.90	3459.42	3196.69	2570.74
ACCUM GOVERNMENT COST INCL TAXES*	0.00	10607.90	28361.44	40769.69	48987.62	55288.91	60433.87	64803.85	68637.76	72097.18	75293.87	102373.44
NPV OF GOVERNMENT COST INCL TAXES*	0.00	8816.44	21527.07	29623.85	34581.19	38063.30	40656.52	42658.16	44246.32	45534.76	46598.68	51468.59

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

200 MILLION LITRES PER YEAR - MIDRANGE CASE
ETHANOL $0.40/LITRE - CAPITAL $160 MILLION - FIXED AND VARIABLE COSTS $0.20/LITRE
SUBSIDY TO ACHIEVE SAME RATE OF RETURN AS 50 PERCENT GOVERNMENT CAPITAL

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (TONNES)	0.00	342857.14	514285.71	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571428.57	571426.57
FEEDSTOCK PRICE ($ PER TONNE)	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
FEEDSTOCK COST ($ 000)	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
PRODUCTION LEVELS												
ETHANOL (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ANIMAL FEED (TONNES)	0.00	109714.29	164571.43	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14	182857.14
CARBON DIOXIDE (TONNES)	0.00	97028.57	145542.86	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29	161714.29
SALES ($ 000)												
ETHANOL	0.00	48000.00	72000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00	80000.00
ANIMAL FEED	0.00	18651.43	27977.14	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71	31085.71
CARBON DIOXIDE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL SALES	0.00	66651.43	99977.14	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71	111085.71
GOVERNMENT SUBSIDY	0.00	4932.00	7398.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00
TOTAL REVENUE	0.00	71583.43	107375.14	119305.71	119305.71	119305.71	119305.71	119305.71	119305.71	119305.71	119305.71	119305.71
COSTS ($ 000)												
OPERATING	0.00	24000.00	36000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00	40000.00
FEEDSTOCK	0.00	37714.29	56571.43	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14	62857.14
TOTAL COST OF SALES	0.00	61714.29	92571.43	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14	102857.14
DEPRECIATION	0.00	27080.00	46101.20	29444.08	16972.88	11268.59	7827.15	5520.67	3925.19	2810.66	2028.72	165.79
TOTAL COSTS	0.00	88794.29	138672.63	132301.22	119830.02	114125.73	110684.29	108377.82	106782.33	105667.80	104885.86	103022.93
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-17210.86	-31297.49	-12995.51	-524.31	5179.99	8621.42	10927.90	12523.38	13637.91	14419.85	16282.79
INCOME TAXES	0.00	0.00	0.00	0.00	0.00	2320.63	3862.40	4895.70	5610.47	6109.78	6460.09	7294.69
NET INCOME	0.00	-17210.86	-31297.49	-12995.51	-524.31	2859.35	4759.02	6032.20	6912.91	7528.13	7959.76	8988.10
CAPITAL (-)	160000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	27080.00	46101.20	29444.08	16972.88	11268.59	7827.15	5520.67	3925.19	2810.66	2028.72	165.79
NET CASH FLOW	-160000.00	9869.14	14803.71	16448.57	16448.57	14127.94	12586.18	11552.87	10838.10	10338.79	9988.48	9153.88
NET PRESENT VALUE AT 10%	-152554.01	-143999.60	-132334.48	-120551.54	-109839.77	-101475.68	-94701.74	-89049.18	-84228.43	-80047.82	-76376.05	-55177.23
NET PRESENT VALUE AT 15%	-149200.77	-141198.14	-130759.93	-120674.70	-111904.94	-105354.95	-100280.86	-96230.85	-92926.99	-90186.43	-87884.07	-77000.58
PRETAX CASH FLOW	-160000.00	9869.14	14803.71	16448.57	16448.57	16448.57	16448.57	16448.57	16448.57	16448.57	16448.57	16448.57
NET PRESENT VALUE AT 10%	-152554.01	-143999.60	-132334.48	-120551.54	-109839.77	-100101.80	-91249.10	-83201.20	-75884.91	-69233.75	-63187.24	-26034.03
NET PRESENT VALUE AT 15%	-149200.77	-141198.14	-130759.93	-120674.70	-111904.94	-104279.05	-97647.85	-91881.59	-86867.45	-82507.33	-78715.92	-59687.70
RATE OF RETURN ON NET CASH FLOW												0.04

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.000	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
UNIT GOVERNMENT SUBSIDY	0.000	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
UNIT BYPRODUCT CREDIT		0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155	0.155
UNIT TOTAL REVENUE		0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597	0.597
UNIT FEEDSTOCK COSTS	0.000	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314	0.314
UNIT OTHER COSTS		0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
UNIT DEPRECIATION		0.226	0.256	0.147	0.085	0.056	0.039	0.028	0.020	0.014	0.010	0.088
UNIT TOTAL COSTS	0.000	0.740	0.770	0.662	0.599	0.571	0.553	0.542	0.534	0.528	0.524	0.602
UNIT PROFIT BEFORE TAX	0.000	-0.143	-0.174	-0.065	-0.003	0.026	0.043	0.055	0.063	0.068	0.072	-0.006
UNIT INCOME TAX		0.000	0.000	0.000	0.000	0.012	0.019	0.024	0.028	0.031	0.032	0.015
UNIT PROFIT AFTER TAX ($)		-0.143	-0.174	-0.065	-0.003	0.014	0.024	0.030	0.035	0.038	0.040	-0.020

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
ETHANOL PRODUCED (000 LITRES)	0.00	120000.00	180000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00	200000.00
ETHANOL SUBSIDY ($ PER LITRE)	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	4932.00	7398.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	4932.00	7398.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00	8220.00
ACCUM GOVERNMENT COST ($ 000)	0.00	4932.00	12330.00	20550.00	28770.00	36990.00	45210.00	53430.00	61650.00	69870.00	78090.00	160290.00
NPV OF GOVERNMENT COST ($ 000)	0.00	3999.23	9215.62	14255.60	18638.20	22449.15	25763.03	28644.65	31150.42	33329.34	35224.06	44733.21
GOVERNMENT COST INCL TAXES*	0.00	4932.00	7398.00	8220.00	8220.00	5899.37	4357.60	3324.30	2609.53	2110.22	1759.91	925.31
ACCUM GOVERNMENT COST INCL TAXES*	0.00	4932.00	12330.00	20550.00	28770.00	34669.37	39026.97	42351.27	44960.80	47071.01	48830.92	59913.55
NPV OF GOVERNMENT COST INCL TAXES*	0.00	3999.23	9215.62	14255.60	18638.20	21445.88	23307.73	24588.95	25499.87	26168.55	26674.71	28588.87

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

NOTE: NET PRESENT VALUES OF GOVERNMENT COSTS ARE DISCOUNTED AT 15%

APPENDIX D

METHANOL BASE CASE AND SENSITIVITIES

METHANOL PLANT MODEL

METHANOL PRICE $0.10 TO 0.25/LITRE

CAPITAL COSTS OF $225 MILLION

FEEDSTOCK(NATURAL GAS) AT $1.00 TO 2.00/MCF
METHANOL YIELD OF 35 LITRES/MCF

100%EQUITY
0% SALVAGE

REAL 1988 CANADIAN DOLLARS

FEDERAL TAX AT 28.0%
PROVINCIAL TAX AT 16%
TOTAL TAX AT 44.0%

NO GOVERNMENT SUBSIDY
NO GOVERNMENT CAPITAL

MONDAY, NOVEMBER 21, 1988.

```
                           BASE CASE:    METHANOL $0.20/LITRE      NATURAL GAS $1.50/MCF
                                  NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

FEEDSTOCK
=========
                                  1988      1989      1990      1991      1992      1993      1994      1995      1996      1997      1998      2000

   FEEDSTOCK PURCHASED (MCF)      0.00  25714.29  27142.86  28571.43  28571.43  28571.43  28571.43  28571.43  28571.43  28571.43  28571.43  28571.43
   FEEDSTOCK PRICE ($ PER MCF)    1.50      1.50      1.50      1.50      1.50      1.50      1.50      1.50      1.50      1.50      1.50      1.50
   FEEDSTOCK COST ($ 000)         0.00  38571.43  40714.29  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14

PRODUCTION LEVELS
=================
   METHANOL (000 LITRES)          0.00 900000.00 950000.00   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000

SALES ($ 000)
=============
   METHANOL                       0.00 180000.00 190000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
   TOTAL SALES                    0.00 180000.00 190000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00
   GOVERNMENT SUBSIDY             0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
   TOTAL REVENUE                  0.00 180000.00 190000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00 200000.00
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------

COSTS ($ 000)
=============
   FEEDSTOCK                      0.00  38571.43  40714.29  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14  42857.14
   OTHER                          0.00  24300.00  25650.00  27000.00  27000.00  27000.00  27000.00  27000.00  27000.00  27000.00  27000.00  27000.00
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
   TOTAL COST OF SALES            0.00  62871.43  66364.29  69857.14  69857.14  69857.14  69857.14  69857.14  69857.14  69857.14  69857.14  69857.14
   DEPRECIATION                   0.00  46543.75  79236.44  50607.01  29172.14  19367.88  13452.92   9488.66   6746.42   4830.82   3486.86    284.94
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
TOTAL COSTS                       0.00 109415.18 145600.72 120464.15  99029.28  89225.02  83310.06  79345.80  76603.57  74687.97  73344.01  70142.09
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------

INCOME ($ 000)
==============
INCOME BEFORE INCOME TAX          0.00  70584.82  44399.28  79535.85 100970.72 110774.98 116689.94 120654.20 123396.43 125312.03 126655.99 129857.91
INCOME TAXES                      0.00  31622.00  19890.88  35632.06  45234.88  49627.19  52277.09  54053.08  55281.60  56139.79  56741.89  58176.35
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
NET INCOME                        0.00  38962.82  24508.40  43903.79  55735.84  61147.79  64412.85  66601.12  68114.83  69172.24  69914.11  71681.57
CAPITAL (-)                  275000.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
DEPRECIATION (+)                  0.00  46543.75  79236.44  50607.01  29172.14  19367.88  13452.92   9488.66   6746.42   4830.82   3486.86    284.94
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
NET CASH FLOW               -275000.00  85506.57 103744.84  94510.80  84907.97  80515.67  77865.76  76089.78  74861.25  74003.07  73400.97  71966.51
NET PRESENT VALUE AT 10%    -250000.00-179333.41-101388.38 -36836.23  15884.94  61333.93 101291.38 136787.82 168536.30 197067.69 222794.28 378639.99
NET PRESENT VALUE AT 15%    -239130.43-174475.18-106261.27 -52224.41 -10010.14  24799.00  54071.63  78945.51 100225.75 118518.18 134295.22 212400.31
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
PRETAX CASH FLOW            -275000.00 117128.57 123635.71 130142.86 130142.86 130142.86 130142.86 130142.86 130142.86 130142.86 130142.86 130142.86
NET PRESENT VALUE AT 10%    -250000.00-153199.53 -60310.19  28579.14 109387.61 182849.86 249633.73 310346.33 365539.60 415715.31 461329.59 741609.58
NET PRESENT VALUE AT 15%    -239130.43-150564.41 -69271.92   5137.68  69841.68 126106.03 175031.55 217575.48 254570.21 286739.53 314712.86 455104.50
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
RATE OF RETURN                                                 0.016     0.129     0.194     0.233     0.259     0.275     0.287     0.295     0.315
                             --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
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INCOME PER UNIT
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                                 1988      1989      1990      1991      1992      1993      1994      1995      1996      1997      1998   10YR AVG

UNIT SELLING PRICE              0.000     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200
UNIT GOVERNMENT SUBSIDY         0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
UNIT TOTAL REVENUE              0.000     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
UNIT FEEDSTOCK COSTS            0.000     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043
UNIT OTHER COSTS                0.000     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027
UNIT DEPRECIATION               0.000     0.052     0.083     0.051     0.029     0.019     0.013     0.009     0.007     0.005     0.003     0.027
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
UNIT TOTAL COSTS                0.000     0.122     0.153     0.120     0.099     0.089     0.083     0.079     0.077     0.075     0.073     0.097
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------

UNIT PROFIT BEFORE TAX          0.000     0.078     0.047     0.080     0.101     0.111     0.117     0.121     0.123     0.125     0.127     0.103
UNIT INCOME TAX                 0.000     0.035     0.021     0.036     0.045     0.050     0.052     0.054     0.055     0.056     0.057     0.046
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
UNIT PROFIT AFTER TAX ($)       0.000     0.043     0.026     0.044     0.056     0.061     0.064     0.067     0.068     0.069     0.070     0.057
                            ========= ========= ========= ========= ========= ========= ========= ========= ========= ========= ========= =========


GOVERNMENT COSTS
----------------

METHANOL PRODUCED (000 LITRES)   0.00 900000.00 950000.00   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000
METHANOL SUBSIDY ($ PER LITRE)   0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
TOTAL GOVERNMENT SUBSIDY ($ 000) 0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
GOVERNMENT CAPITAL ($ 000)       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                            --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------

GOVERNMENT COST ($ 000)          0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
ACCUM GOVERNMENT COST ($ 000)    0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
NPV OF GOVERNMENT COST ($ 000)   0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                            ========= ========= ========= ========= ========= ========= ========= ========= ========= ========= ========= =========

GOVERNMENT COST INCL TAXES*      0.00 -31622.00 -19890.88 -35632.06 -45234.88 -49627.19 -52277.09 -54053.08 -55281.60 -56139.79 -56741.89 -58176.35
ACCUM GOVERNMENT COST INCL TAXES* 0.00 -31622.00 -51512.88 -87144.94-132379.82-182007.01-234284.10-288337.18-343618.79-399758.58-456500.46-1035119.4
NPV OF GOVERNMENT COST INCL TAXES* 0.00 -27497.39 -42537.75 -65966.41 -91829.60-116503.08-139103.91-159424.47-177496.12-193454.56-207480.28-279109.82
                            ========= ========= ========= ========= ========= ========= ========= ========= ========= ========= ========= =========
* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
```

METHANOL PRICE SENSITIVITY I: METHANOL $0.10/LITRE NATURAL GAS $1.50/MCF
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (MCF)	0.00	25714.29	27142.86	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER MCF)	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
FEEDSTOCK COST ($ 000)	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
PRODUCTION LEVELS												
METHANOL (000 LITRES)	0.00	900000	950000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
SALES ($ 000)												
METHANOL	0.00	90000.00	95000.00	100000	100000	100000	100000	100000	100000	100000	100000	100000
TOTAL SALES	0.00	90000.00	95000.00	100000	100000	100000	100000	100000	100000	100000	100000	100000
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	90000.00	95000.00	100000	100000	100000	100000	100000	100000	100000	100000	100000
COSTS ($ 000)												
FEEDSTOCK	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
OTHER	0.00	24300.00	25650.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00
TOTAL COST OF SALES	0.00	62871.43	66364.29	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14
DEPRECIATION	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
TOTAL COSTS	0.00	109415.2	145600.7	120464.2	99029.28	89225.02	83310.06	79345.80	76603.57	74687.97	73344.01	70142.09
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	-19415.18	-50600.72	-20464.15	970.72	10774.98	16689.94	20654.20	23396.43	25312.03	26655.99	29857.91
INCOME TAXES	0.00	0.00	0.00	0.00	434.88	4827.19	7477.09	9253.08	10481.60	11339.79	11941.89	13376.35
NET INCOME	0.00	-19415.18	-50600.72	-20464.15	535.84	5947.79	9212.85	11401.12	12914.83	13972.24	14714.11	16481.57
CAPITAL (-)	275000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
NET CASH FLOW	-275000	27128.57	28635.71	30142.86	29707.97	25315.67	22665.76	20889.78	19661.25	18803.07	18200.97	16766.51
NET PRESENT VALUE AT 10%	-250000	-227579.7	-206065.3	-185477.3	-167031	-152740.9	-141109.8	-131364.6	-123026.3	-115776.9	-109397.6	-72432.41
NET PRESENT VALUE AT 15%	-239130.4	-218617.3	-199788.9	-182554.6	-167784.5	-156839.8	-148318.9	-141490	-135901.1	-131253.2	-127341.1	-108783
PRETAX CASH FLOW	-275000	27128.57	28635.71	30142.86	30142.86	30142.86	30142.86	30142.86	30142.86	30142.86	30142.86	30142.86
NET PRESENT VALUE AT 10%	-250000	-227579.7	-206065.3	-185477.3	-166760.9	-149746.1	-134278	-120216.2	-107432.6	-95811.27	-85246.39	-20329.72
NET PRESENT VALUE AT 15%	-239130.4	-218617.3	-199788.9	-182554.6	-167568.3	-154536.7	-143204.9	-133351.1	-124782.6	-117331.8	-110852.8	-78336.17
												0.048

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT TOTAL REVENUE	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
UNIT FEEDSTOCK COSTS	0.000	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
UNIT OTHER COSTS	0.000	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
UNIT DEPRECIATION	0.000	0.052	0.083	0.051	0.029	0.019	0.013	0.009	0.007	0.005	0.003	0.027
UNIT TOTAL COSTS	0.000	0.122	0.153	0.120	0.099	0.089	0.083	0.079	0.077	0.075	0.073	0.097
UNIT PROFIT BEFORE TAX	0.000	-0.022	-0.053	-0.020	0.001	0.011	0.017	0.021	0.023	0.025	0.027	0.003
UNIT INCOME TAX	0.000	0.000	0.000	0.000	0.000	0.005	0.007	0.009	0.010	0.011	0.012	0.006
UNIT PROFIT AFTER TAX ($)	0.000	-0.022	-0.053	-0.020	0.001	0.006	0.009	0.011	0.013	0.014	0.015	-0.003

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
METHANOL PRODUCED (000 LITRES)	0.00	900000	950000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
METHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-434.88	-4827.19	-7477.09	-9253.08	-10481.60	-11339.79	-11941.89	-13376.35
ACCUM GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-434.88	-5262.07	-12739.17	-21992.25	-32473.85	-43813.64	-55755.53	-186374.5
NPV OF GOVERNMENT COST INCL TAXES*	0.00	0.00	0.00	0.00	-248.65	-2648.61	-5881.17	-9359.74	-12786.20	-16009.67	-18961.52	-35013.84

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

BASE CASE: METHANOL $0.14/LITRE NATURAL GAS $1.50/MCF
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

FEEDSTOCK	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK PURCHASED (MCF)	0.00	25714.29	27142.86	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER MCF)	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
FEEDSTOCK COST ($ 000)	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
PRODUCTION LEVELS												
METHANOL (000 LITRES)	0.00	900000.00	950000.00	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
SALES ($ 000)												
METHANOL	0.00	126000.00	133000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00
TOTAL SALES	0.00	126000.00	133000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	126000.00	133000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00	140000.00
COSTS ($ 000)												
FEEDSTOCK	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
OTHER	0.00	24300.00	25650.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00
TOTAL COST OF SALES	0.00	62871.43	66364.29	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14
DEPRECIATION	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
TOTAL COSTS	0.00	109415.18	145600.72	120464.15	99029.28	89225.02	83310.06	79345.80	76603.57	74687.97	73344.01	70142.09
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	16584.82	-12600.72	19535.85	40970.72	50774.98	56689.94	60654.20	63396.43	65312.03	66655.99	69857.91
INCOME TAXES	0.00	7430.00	0.00	8752.06	18354.88	22747.19	25397.09	27173.08	28401.60	29259.79	29861.89	31296.35
NET INCOME	0.00	9154.82	-12600.72	10783.79	22615.84	28027.79	31292.85	33481.12	34994.83	36052.24	36794.11	38561.57
CAPITAL (-)	275000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
NET CASH FLOW	-275000.00	55698.57	66635.71	61390.80	51787.97	47395.67	44745.76	42969.78	41741.25	40883.07	40280.97	38846.51
NET PRESENT VALUE AT 10%	-250000.00	-203968.12	-153903.72	-111972.98	-79816.73	-53063.11	-30101.46	-10055.74	7646.63	23408.82	37527.05	122044.43
NET PRESENT VALUE AT 15%	-239130.43	-197014.31	-153200.25	-118099.86	-92352.09	-71861.63	-55040.04	-40993.14	-29127.67	-19022.01	-10363.88	32013.00
PRETAX CASH FLOW	-275000.00	63128.57	66635.71	70142.86	70142.86	70142.86	70142.86	70142.86	70142.86	70142.86	70142.86	70142.86
NET PRESENT VALUE AT 10%	-250000.00	-197827.63	-147763.23	-99854.71	-56301.52	-16707.70	19286.67	52008.83	81756.25	108799.36	133384.00	284446.00
NET PRESENT VALUE AT 15%	-239130.43	-191396.17	-147582.10	-107477.70	-72604.30	-42279.61	-15910.31	7019.52	26958.49	44296.74	59373.47	135040.10
RATE OF RETURN						0.010	0.056	0.087	0.109	0.125	0.137	0.177

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT TOTAL REVENUE	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
UNIT FEEDSTOCK COSTS	0.000	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
UNIT OTHER COSTS	0.000	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
UNIT DEPRECIATION	0.000	0.052	0.083	0.051	0.029	0.019	0.013	0.009	0.007	0.005	0.003	0.027
UNIT TOTAL COSTS	0.000	0.122	0.153	0.120	0.099	0.089	0.083	0.079	0.077	0.075	0.073	0.097
UNIT PROFIT BEFORE TAX	0.000	0.018	-0.013	0.020	0.041	0.051	0.057	0.061	0.063	0.065	0.067	0.043
UNIT INCOME TAX	0.000	0.008	0.000	0.009	0.018	0.023	0.025	0.027	0.028	0.029	0.030	0.020
UNIT PROFIT AFTER TAX ($)	0.000	0.010	-0.013	0.011	0.023	0.028	0.031	0.033	0.035	0.036	0.037	0.023

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
METHANOL PRODUCED (000 LITRES)	0.00	900000.00	950000.00	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
METHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	-7430.00	0.00	-8752.06	-18354.88	-22747.19	-25397.09	-27173.08	-28401.60	-29259.79	-29861.89	-31296.35
ACCUM GOVERNMENT COST INCL TAXES*	0.00	-7430.00	-7430.00	-16182.06	-34536.94	-57284.13	-82681.23	-109854.31	-138255.91	-167515.70	-197377.59	-507196.56
NPV OF GOVERNMENT COST INCL TAXES*	0.00	-6460.87	-6460.87	-12215.49	-22709.96	-34019.33	-44999.19	-55214.56	-64499.09	-72816.55	-80197.96	-118481.16

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

METHANOL PRICE SENSITIVITY II: METHANOL $0.15/LITRE   NATURAL GAS $1.50/MCF
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (MCF)	0.00	25714.29	27142.86	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER MCF)	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
FEEDSTOCK COST ($ 000)	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
PRODUCTION LEVELS												
METHANOL (000 LITRES)	0.00	900000	950000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
SALES ($ 000)												
METHANOL	0.00	135000	142500	150000	150000	150000	150000	150000	150000	150000	150000	150000
TOTAL SALES	0.00	135000	142500	150000	150000	150000	150000	150000	150000	150000	150000	150000
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	135000	142500	150000	150000	150000	150000	150000	150000	150000	150000	150000
COSTS ($ 000)												
FEEDSTOCK	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
OTHER	0.00	24300.00	25650.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00
TOTAL COST OF SALES	0.00	62871.43	66364.29	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14
DEPRECIATION	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
TOTAL COSTS	0.00	109415.2	145600.7	120464.2	99029.28	89225.02	83310.06	79345.80	76603.57	74687.97	73344.01	70142.09
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	25584.82	-3100.72	29535.85	50970.72	60774.98	66689.94	70654.20	73396.43	75312.03	76655.99	79857.91
INCOME TAXES	0.00	11462.00	0.00	13232.06	22834.88	27227.19	29877.09	31653.08	32881.60	33739.79	34341.89	35776.35
NET INCOME	0.00	14122.82	-3100.72	16303.79	28135.84	33547.79	36812.85	39001.12	40514.83	41572.24	42314.11	44081.57
CAPITAL (-)	275000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
NET CASH FLOW	-275000	60666.57	76135.71	66910.80	57307.97	52915.67	50265.76	48489.78	47261.25	46403.07	45800.97	44366.51
NET PRESENT VALUE AT 10%	-250000	-199862.3	-142660.4	-96959.47	-61375.73	-31506.22	-5711.93	16908.91	36952.29	54842.68	70895.64	167301.1
NET PRESENT VALUE AT 15%	-239130.4	-193257.8	-143197.3	-104940.9	-76448.67	-53571.76	-34675.00	-18823.61	-5389.01	6081.12	15925.73	64257.32
PRETAX CASH FLOW	-275000	72128.57	76135.71	80142.86	80142.86	80142.86	80142.86	80142.86	80142.86	80142.86	80142.86	80142.86
NET PRESENT VALUE AT 10%	-250000	-190389.6	-133187.7	-78449.07	-28686.66	16551.89	57677.85	95065.08	129053.5	159952	188041.6	360639.9
NET PRESENT VALUE AT 15%	-239130.4	-184590.9	-134530.4	-88708.47	-48863.30	-14215.33	15913.34	42112.18	64893.78	84703.87	101930	188384.2
RATE OF RETURN						0.048	0.092	0.122	0.143	0.158	0.169	0.204

INCOME PER UNIT

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
UNIT SELLING PRICE	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
UNIT GOVERNMENT SUBSIDY	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
UNIT TOTAL REVENUE	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
UNIT FEEDSTOCK COSTS	0.000	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
UNIT OTHER COSTS	0.000	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
UNIT DEPRECIATION	0.000	0.052	0.083	0.051	0.029	0.019	0.013	0.009	0.007	0.005	0.003	0.027
UNIT TOTAL COSTS	0.000	0.122	0.153	0.120	0.099	0.089	0.083	0.079	0.077	0.075	0.073	0.097
UNIT PROFIT BEFORE TAX	0.000	0.028	-0.003	0.030	0.051	0.061	0.067	0.071	0.073	0.075	0.077	0.053
UNIT INCOME TAX	0.000	0.013	0.000	0.013	0.023	0.027	0.030	0.032	0.033	0.034	0.034	0.024
UNIT PROFIT AFTER TAX ($)	0.000	0.016	-0.003	0.016	0.028	0.034	0.037	0.039	0.041	0.042	0.042	0.029

GOVERNMENT COSTS

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	10YR AVG
METHANOL PRODUCED (000 LITRES)	0.00	900000	950000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
METHANOL SUBSIDY ($ PER LITRE)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL GOVERNMENT SUBSIDY ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT CAPITAL ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACCUM GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NPV OF GOVERNMENT COST ($ 000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOVERNMENT COST INCL TAXES*	0.00	-11462.00	0.00	-13232.06	-22834.88	-27227.19	-29877.09	-31653.08	-32881.60	-33739.79	-34341.89	-35776.35
ACCUM GOVERNMENT COST INCL TAXES*	0.00	-11462.00	-11462.00	-24694.06	-47528.94	-74756.13	-104633.2	-136286.3	-169167.9	-202907.7	-237249.6	-591868.6
NPV OF GOVERNMENT COST INCL TAXES*	0.00	-9966.96	-9966.96	-18667.25	-31723.17	-45259.89	-58176.59	-70076.15	-80825.21	-90416.16	-98904.95	-142745.9

* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT

METHANOL PRICE SENSITIVITY III: METHANOL $0.25/LITRE NATURAL GAS $1.50/MCF
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (MCF)	0.00	25714.29	27142.86	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER MCF)	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
FEEDSTOCK COST ($ 000)	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
PRODUCTION LEVELS												
METHANOL (000 LITRES)	0.00	900000	950000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
SALES ($ 000)												
METHANOL	0.00	225000	237500	250000	250000	250000	250000	250000	250000	250000	250000	250000
TOTAL SALES	0.00	225000	237500	250000	250000	250000	250000	250000	250000	250000	250000	250000
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	225000	237500	250000	250000	250000	250000	250000	250000	250000	250000	250000
COSTS ($ 000)												
FEEDSTOCK	0.00	38571.43	40714.29	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14	42857.14
OTHER	0.00	24300.00	25650.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00
TOTAL COST OF SALES	0.00	62871.43	66364.29	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14	69857.14
DEPRECIATION	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
TOTAL COSTS	0.00	109415.2	145600.7	120464.2	99029.28	89225.02	83310.06	79345.80	76603.57	74687.97	73344.01	70142.09
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	115584.8	91899.28	129535.8	150970.7	160775	166689.9	170654.2	173396.4	175312	176656	179857.9
INCOME TAXES	0.00	51782.00	41170.88	58032.06	67634.88	72027.19	74677.09	76453.08	77681.60	78539.79	79141.89	80576.35
NET INCOME	0.00	63802.82	50728.40	71503.79	83335.84	88747.79	92012.85	94201.12	95714.83	96772.24	97514.11	99281.57
CAPITAL (-)	275000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
NET CASH FLOW	-275000	110346.6	129964.8	122110.8	112508	108115.7	105465.8	103689.8	102461.3	101603.1	101001	99566.51
NET PRESENT VALUE AT 10%	-250000	-158804.5	-61159.98	22243.34	92101.94	153130.4	207251	255623.1	299076.6	338249	373649.3	588935.2
NET PRESENT VALUE AT 15%	-239130.4	-155692.6	-70238.58	-421.34	55515.01	102256.4	141904.9	175801.3	204927.1	230041.9	251751.3	359629.9
PRETAX CASH FLOW	-275000	162128.6	171135.7	180142.9	180142.9	180142.9	180142.9	180142.9	180142.9	180142.9	180142.9	180142.9
NET PRESENT VALUE AT 10%	-250000	-116009.4	12567.35	135607.3	247461.9	349147.8	441589.6	525627.6	602025.7	671478.6	734617.6	1122579
NET PRESENT VALUE AT 15%	-239130.4	-116537.9	-4013.43	98983.83	188546.7	266427.4	334149.8	393038.8	444246.6	488775.2	527495.7	721824.8

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INCOME PER UNIT
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                                    1988      1989      1990      1991      1992      1993      1994      1995      1996      1997      1998  10YR AVG

UNIT SELLING PRICE                 0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250
UNIT GOVERNMENT SUBSIDY            0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
                                --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT TOTAL REVENUE                 0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250     0.250
                                --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT FEEDSTOCK COSTS               0.000     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043     0.043
UNIT OTHER COSTS                   0.000     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027
UNIT DEPRECIATION                  0.000     0.052     0.083     0.051     0.029     0.019     0.013     0.009     0.007     0.005     0.003     0.027
                                --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT TOTAL COSTS                   0.000     0.122     0.153     0.120     0.099     0.089     0.083     0.079     0.077     0.075     0.073     0.097
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UNIT PROFIT BEFORE TAX             0.000     0.128     0.097     0.130     0.151     0.161     0.167     0.171     0.173     0.175     0.177     0.153
UNIT INCOME TAX                    0.000     0.058     0.043     0.058     0.068     0.072     0.075     0.076     0.078     0.079     0.079     0.069
                                --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT PROFIT AFTER TAX ($)          0.000     0.071     0.053     0.072     0.083     0.089     0.092     0.094     0.096     0.097     0.098     0.084
                                ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========


GOVERNMENT COSTS
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METHANOL PRODUCED (000 LITRES)     0.000    900000    950000   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000
METHANOL SUBSIDY ($ PER LITRE)     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
                                --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
TOTAL GOVERNMENT SUBSIDY ($ 000)   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
                                --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
GOVERNMENT CAPITAL ($ 000)         0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
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GOVERNMENT COST ($ 000)            0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
ACCUM GOVERNMENT COST ($ 000)      0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
NPV OF GOVERNMENT COST ($ 000)     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
                                ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========

GOVERNMENT COST INCL TAXES*        0.000    -51782-41170.88-58032.06-67634.88-72027.19-74677.09-76453.08 -77681.6-78539.79-79141.89-80576.35
ACCUM GOVERNMENT COST INCL TAXES*  0.000    -51782-92952.88-150984.9-218619.8  -290647-365324.1-441777.2-519458.8-597998.6-677140.5- 1479759
NPV OF GOVERNMENT COST INCL TAXES* 0.000-45027.83-76158.92-114315.9-152986.4-188796.7-221081.6-249823.2-275217.4-297543.3  -317106-416524.1
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* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
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                                       NATURAL GAS PRICE SENSITIVITY I:    METHANOL $0.20/LITRE      NATURAL GAS $1.00/MCF
                                                  NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY
FEEDSTOCK
=========
                                  1988     1989     1990     1991     1992     1993     1994     1995     1996     1997     1998     2008

  FEEDSTOCK PURCHASED (MCF)       0.00 25714.29 27142.86 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43
  FEEDSTOCK PRICE ($ PER MCF)     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00     1.00
  FEEDSTOCK COST ($ 000)          0.00 25714.29 27142.86 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43

PRODUCTION LEVELS
=================
  METHANOL (000 LITRES)           0.00   900000   950000  1000000  1000000  1000000  1000000  1000000  1000000  1000000  1000000  1000000

SALES ($ 000)
=============
  METHANOL                        0.00   180000   190000   200000   200000   200000   200000   200000   200000   200000   200000   200000
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
  TOTAL SALES                     0.00   180000   190000   200000   200000   200000   200000   200000   200000   200000   200000   200000
  GOVERNMENT SUBSIDY              0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
  TOTAL REVENUE                   0.00   180000   190000   200000   200000   200000   200000   200000   200000   200000   200000   200000
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------

COSTS ($ 000)
=============
  FEEDSTOCK                       0.00 25714.29 27142.86 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43 28571.43
  OTHER                           0.00 24300.00 25650.00 27000.00 27000.00 27000.00 27000.00 27000.00 27000.00 27000.00 27000.00 27000.00
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
  TOTAL COST OF SALES             0.00 50014.29 52792.86 55571.43 55571.43 55571.43 55571.43 55571.43 55571.43 55571.43 55571.43 55571.43
  DEPRECIATION                    0.00 46543.75 79236.44 50607.01 29172.14 19367.88 13452.92  9488.66  6746.42  4830.82  3486.86   284.94
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
TOTAL COSTS                       0.00 96558.04 132029.3 106178.4 84743.56 74939.31 69024.34 65060.09 62317.85 60402.25 59058.29 55856.37
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------

INCOME ($ 000)
==============
INCOME BEFORE INCOME TAX          0.00 83441.96 57970.71 93821.56 115256.4 125060.7 130975.7 134939.9 137682.1 139597.7 140941.7 144143.6
INCOME TAXES                      0.00 37382.00 25970.88 42032.06 51634.88 56027.19 58677.09 60453.08 61681.60 62539.79 63141.89 64576.35
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
NET INCOME                        0.00 46059.96 31999.83 51789.50 63621.55 69033.50 72298.56 74486.83 76000.55 77057.96 77799.82 79567.28
CAPITAL (-)                     275000     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
DEPRECIATION (+)                  0.00 46543.75 79236.44 50607.01 29172.14 19367.88 13452.92  9488.66  6746.42  4830.82  3486.86   284.94
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
NET CASH FLOW                  -275000 92603.71 111236.3 102396.5 92793.69 88401.38 85751.48 83975.49 82746.97 81888.78 81286.69 79852.23
NET PRESENT VALUE AT 10%       -250000  -173468-89894.55-19956.36 37661.22 87561.50 131565.6 170740.8 205833.5 237405.2 265895.7 438724.3
NET PRESENT VALUE AT 15%     -239130.4-169108.7-95969.07-37423.53  8711.33 46929.69 79166.84 106618.6 130140.4 150382.1 167854.1 254465.9
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
PRETAX CASH FLOW               -275000 129985.7 137207.1 144428.6 144428.6 144428.6 144428.6 144428.6 144428.6 144428.6 144428.6 144428.6
NET PRESENT VALUE AT 10%       -250000-142573.8-39488.03 59158.62 148837.4 230363.6 304478.3 371855.3 433107.1 488790.5 539411.9   850458
NET PRESENT VALUE AT 15%     -239130.4-140842.6-50626.64 31950.87 103757.4 166197.9 220493.9 267707.9 308763.5   344464 375507.9 531310.3
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
RATE OF RETURN                                               0.055    0.168    0.231    0.270    0.294    0.309    0.320    0.327    0.345
                              -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
```

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INCOME PER UNIT
===============

                                              1988      1989      1990      1991      1992      1993      1994      1995      1996      1997      1998 10YR AVG

UNIT SELLING PRICE                           0.000     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200
UNIT GOVERNMENT SUBSIDY                      0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT TOTAL REVENUE                           0.000     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200     0.200
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT FEEDSTOCK COSTS                         0.000     0.029     0.029     0.029     0.029     0.029     0.029     0.029     0.029     0.029     0.029     0.029
UNIT OTHER COSTS                             0.000     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027     0.027
UNIT DEPRECIATION                            0.000     0.052     0.083     0.051     0.029     0.019     0.013     0.009     0.007     0.005     0.003     0.027
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT TOTAL COSTS                             0.000     0.107     0.139     0.106     0.085     0.075     0.069     0.065     0.062     0.060     0.059     0.083
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------

UNIT PROFIT BEFORE TAX                       0.000     0.093     0.061     0.094     0.115     0.125     0.131     0.135     0.138     0.140     0.141     0.117
UNIT INCOME TAX                              0.000     0.042     0.027     0.042     0.052     0.056     0.059     0.060     0.062     0.063     0.063     0.053
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
UNIT PROFIT AFTER TAX ($)                    0.000     0.051     0.034     0.052     0.064     0.069     0.072     0.074     0.076     0.077     0.078     0.065
                                          ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========


GOVERNMENT COSTS
================

METHANOL PRODUCED (000 LITRES)                0.00    900000    950000   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000   1000000
METHANOL SUBSIDY ($ PER LITRE)                0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
TOTAL GOVERNMENT SUBSIDY ($ 000)              0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
GOVERNMENT CAPITAL ($ 000)                    0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                                          --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------

GOVERNMENT COST ($ 000)                       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
ACCUM GOVERNMENT COST ($ 000)                 0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
NPV OF GOVERNMENT COST ($ 000)                0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
                                          ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========

GOVERNMENT COST INCL TAXES*                   0.00-37382.00-25970.88-42032.06-51634.88-56027.19-58677.09-60453.08-61681.60-62539.79-63141.89-64576.35
ACCUM GOVERNMENT COST INCL TAXES*             0.00-37382.00-63352.88-105384.9-157019.8  -213047-271724.1-332177.2-393858.8-456398.6-519540.5- 1162159
NPV OF GOVERNMENT COST INCL TAXES*            0.00-32506.09-52143.80-79780.56  -109303-137158.4-162526.1-185252.7-205416.5-223194.2-238801.9-318371.1
                                          ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
```

METHANOL PRICE SENSITIVITY II: METHANOL $0.20/LITRE NATURAL GAS $2.00/MCF
NO GOVERNMENT CAPITAL - NO GOVERNMENT SUBSIDY

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2008
FEEDSTOCK												
FEEDSTOCK PURCHASED (MCF)	0.00	25714.29	27142.86	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43	28571.43
FEEDSTOCK PRICE ($ PER MCF)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
FEEDSTOCK COST ($ 000)	0.00	51428.57	54285.71	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86
PRODUCTION LEVELS												
METHANOL (000 LITRES)	0.00	900000	950000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
SALES ($ 000)												
METHANOL	0.00	180000	190000	200000	200000	200000	200000	200000	200000	200000	200000	200000
TOTAL SALES	0.00	180000	190000	200000	200000	200000	200000	200000	200000	200000	200000	200000
GOVERNMENT SUBSIDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL REVENUE	0.00	180000	190000	200000	200000	200000	200000	200000	200000	200000	200000	200000
COSTS ($ 000)												
FEEDSTOCK	0.00	51428.57	54285.71	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86	57142.86
OTHER	0.00	24300.00	25650.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00	27000.00
TOTAL COST OF SALES	0.00	75728.57	79935.71	84142.86	84142.86	84142.86	84142.86	84142.86	84142.86	84142.86	84142.86	84142.86
DEPRECIATION	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
TOTAL COSTS	0.00	122272.3	159172.2	134749.9	113315	103510.7	97595.77	93631.51	90889.28	88973.68	87629.72	84427.80
INCOME ($ 000)												
INCOME BEFORE INCOME TAX	0.00	57727.68	30827.85	65250.13	86685.01	96489.26	102404.2	106368.5	109110.7	111026.3	112370.3	115572.2
INCOME TAXES	0.00	25862.00	13810.88	29232.06	38834.88	43227.19	45877.09	47653.08	48881.60	49739.79	50341.89	51776.35
NET INCOME	0.00	31865.68	17016.97	36018.07	47850.12	53262.07	56527.13	58715.40	60229.12	61286.53	62028.39	63795.85
CAPITAL (-)	275000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEPRECIATION (+)	0.00	46543.75	79236.44	50607.01	29172.14	19367.88	13452.92	9488.66	6746.42	4830.82	3486.86	284.94
NET CASH FLOW	-275000	78409.43	96253.41	86625.08	77022.26	72629.95	69980.05	68204.06	66975.54	66117.35	65515.26	64080.80
NET PRESENT VALUE AT 10%	-250000	-185198.8	-112882.2	-53716.11	-5891.35	35106.37	71017.20	102834.9	131239.1	156730.2	179692.9	318555.6
NET PRESENT VALUE AT 15%	-239130.4	-179841.6	-116553.5	-67025.29	-28731.61	2668.32	28976.41	51272.44	70311.07	86654.27	100736.3	170334.7
PRETAX CASH FLOW	-275000	104271.4	110064.3	115857.1	115857.1	115857.1	115857.1	115857.1	115857.1	115857.1	115857.1	115857.1
NET PRESENT VALUE AT 10%	-250000	-163825.3	-81132.34	-2000.35	69937.82	135336.2	194789.2	248837.4	297972.1	342640.1	383247.3	632761.1
NET PRESENT VALUE AT 15%	-239130.4	-160286.3	-87917.20	-21675.50	35925.97	86014.21	129569.2	167443.1	200376.9	229015.1	253917.8	378898.7
RATE OF RETURN					0.089	0.155	0.196	0.222	0.240	0.252	0.261	0.285

```
INCOME PER UNIT
---------------

                                       1988     1989     1990     1991     1992     1993     1994     1995     1996     1997     1998 10YR AVG

UNIT SELLING PRICE                    0.000    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200
UNIT GOVERNMENT SUBSIDY               0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
UNIT TOTAL REVENUE                    0.000    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200    0.200
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
UNIT FEEDSTOCK COSTS                  0.000    0.057    0.057    0.057    0.057    0.057    0.057    0.057    0.057    0.057    0.057    0.057
UNIT OTHER COSTS                      0.000    0.027    0.027    0.027    0.027    0.027    0.027    0.027    0.027    0.027    0.027    0.027
UNIT DEPRECIATION                     0.000    0.052    0.083    0.051    0.029    0.019    0.013    0.009    0.007    0.005    0.003    0.027
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
UNIT TOTAL COSTS                      0.000    0.136    0.168    0.135    0.113    0.104    0.098    0.094    0.091    0.089    0.088    0.111
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------

UNIT PROFIT BEFORE TAX                0.000    0.064    0.032    0.065    0.087    0.096    0.102    0.106    0.109    0.111    0.112    0.089
UNIT INCOME TAX                       0.000    0.029    0.015    0.029    0.039    0.043    0.046    0.048    0.049    0.050    0.050    0.040
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
UNIT PROFIT AFTER TAX ($)             0.000    0.035    0.018    0.036    0.048    0.053    0.057    0.059    0.060    0.061    0.062    0.049
                                   ======== ======== ======== ======== ======== ======== ======== ======== ======== ======== ======== ========


GOVERNMENT COSTS
----------------

METHANOL PRODUCED (000 LITRES)         0.00   900000   950000  1000000  1000000  1000000  1000000  1000000  1000000  1000000  1000000  1000000
METHANOL SUBSIDY ($ PER LITRE)         0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
TOTAL GOVERNMENT SUBSIDY ($ 000)       0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------
GOVERNMENT CAPITAL ($ 000)             0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
                                   -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- -------- --------

GOVERNMENT COST ($ 000)                0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
ACCUM GOVERNMENT COST ($ 000)          0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
NPV OF GOVERNMENT COST ($ 000)         0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
                                   ======== ======== ======== ======== ======== ======== ======== ======== ======== ======== ======== ========

GOVERNMENT COST INCL TAXES*            0.00-25862.00-13810.88-29232.06-38834.88-43227.19-45877.09-47653.08-48881.60-49739.79-50341.89-51776.35
ACCUM GOVERNMENT COST INCL TAXES*      0.00-25862.00-39672.88-68904.94-107739.8  -150967-196844.1-244497.2-293378.8-343118.6-393460.5-908079.4
NPV OF GOVERNMENT COST INCL TAXES*     0.00-22488.70-32931.70-52152.26-74356.23-95847.78-115681.7-133596.3-149575.8-163714.9-176158.7-239848.6
                                   ======== ======== ======== ======== ======== ======== ======== ======== ======== ======== ======== ========
* THESE VALUES WILL BE NEGATIVE IF TAX INCOME EXCEEDS CAPITAL AND SUBSIDIES PAID OUT
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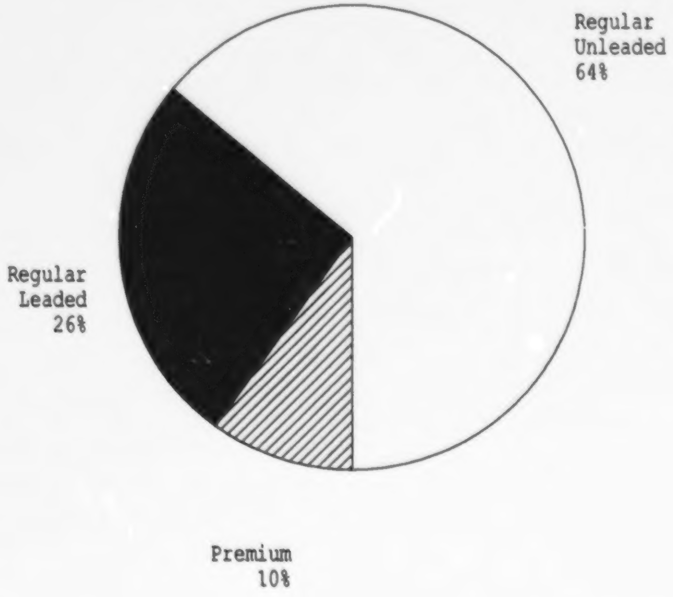
APPENDIX E

REGIONAL ANALYSIS

Figure E.1

Canadian Motor Gasoline
Percentage Of Sales By Grade
June 1987 - May 1988



SOURCE: Octane Week, October 3, 1988.

REGIONAL ALTERNATIVE FUEL
DEMAND ANALYSIS

NATIONAL MOTOR GASOLINE CONSUMPTION
PROJECTED TO HAVE NO GROWTH AFTER 1988

FUEL ENERGY COMPARISONS MADE ON A STRICTLY VOLUMETRIC BASIS

PENETRATION ASSUMPTIONS:
SCENARIO I: E10 (GASOHOL) PENETRATES 25% OF THE REGULAR UNLEADED MARKET BY 1993
SCENARIO II: ESP (PREMIUM PLUS) PENETRATES 25% OF THE PREMIUM UNLEADED MARKET BY 1993
SCENARIO III: M85 (NEAT METHANOL) PENETRATES 10% OF THE TOTAL UNLEADED MARKET BY 1993
SCENARIO IV: M100 (METHANOL) PENETRATES 25% OF THE DIESEL MARKET BY 1993

FRIDAY, OCTOBER 21, 1988.

ETHANOL DEMAND
BASED ON PENETRATION OF THE E10 BLEND
REPLACING 5% OF TOTAL UNLEADED DEMAND IN 1989, 10% IN 1990, 15% IN 1991, 20% IN 1992, AND 25% IN 1993

NOTE: ALL VOLUMES IN THOUSANDS OF LITRES

ETHANOL	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ATLANTIC	15942.215	31615.269	47019.162	62153.895	77019.468	76346.566	75673.665	75000.763	74327.862	73654.961
QUEBEC	39565.073	77294.493	113188.259	147246.371	179468.830	174879.696	170290.562	165701.428	161112.294	156523.160
ONTARIO	75576.863	152242.942	229998.239	308842.752	388776.482	391499.523	394222.565	396945.607	399668.649	402391.691
MANITOBA	6216.081	12598.103	19146.066	25859.970	32739.814	33154.666	33569.519	33984.371	34399.223	34814.076
SASK NWT	6509.974	13529.712	21059.212	29098.476	37647.503	38921.911	40196.319	41470.727	42745.135	44019.543
ALBERTA	17032.718	34234.261	51604.629	69143.823	86851.842	87273.905	87695.969	88118.032	88540.095	88962.158
BRITISH COLUMBIA	15396.225	30941.628	46636.209	62479.969	78472.908	78845.854	79218.800	79591.746	79964.692	80337.638
YUKON	185.722	393.334	622.835	874.226	1147.506	1202.230	1256.954	1311.678	1366.402	1421.126
CANADA	176424.870	352849.741	529274.611	705699.482	882124.352	882124.352	882124.352	882124.352	882124.352	882124.352

ETHANOL DEMAND
BASED ON PENETRATION OF THE ESP BLEND
REPLACING 5% OF PREMIUM UNLEADED DEMAND IN 1989, 10% IN 1990, 15% IN 1991, 20% IN 1992, AND 25% IN 1993

NOTE: ALL VOLUMES IN THOUSANDS OF LITRES

ETHANOL

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ATLANTIC	1124.631	2220.242	3286.832	4324.402	5332.951	5260.400	5187.848	5115.297	5042.746	4970.194
QUEBEC	5666.515	10938.287	15815.316	20297.601	24385.144	23398.285	22411.427	21424.568	20437.710	19450.852
ONTARIO	7461.224	15204.275	23229.153	31535.858	40124.390	40828.958	41533.526	42238.094	42942.662	43647.230
MANITOBA	290.793	597.561	920.304	1259.023	1613.716	1653.654	1693.592	1733.530	1773.468	1813.405
SASK NWT	326.458	685.493	1077.105	1501.295	1958.061	2039.504	2120.947	2202.390	2283.833	2365.275
ALBERTA	1033.724	2045.369	3034.934	4002.421	4947.828	4892.630	4837.432	4782.233	4727.035	4671.837
BRITISH COLUMBIA	2136.332	4388.288	6755.869	9239.073	11837.901	12126.961	12416.021	12705.081	12994.141	13283.201
YUKON	1.396	2.631	3.706	4.621	5.375	4.974	4.573	4.172	3.771	3.370
CANADA	18041.073	36082.146	54123.220	72164.293	90205.366	90205.366	90205.366	90205.366	90205.366	90205.366

METHANOL DEMAND
BASED ON PENETRATION OF THE M85 BLEND
REPLACING 2% OF TOTAL UNLEADED DEMAND IN 1989, 4% IN 1990, 6% IN 1991, 8% IN 1992, AND 10% IN 1993

NOTE: ALL VOLUMES IN THOUSANDS OF LITRES

METHANOL	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ATLANTIC	90967.663	180399.472	268295.428	354655.531	439479.779	435640.146	431800.512	427960.878	424121.244	420281.610
QUEBEC	225761.748	441049.097	645862.047	840200.598	1024064.750	997878.752	971692.754	945506.757	919320.759	893134.761
ONTARIO	431248.151	868711.468	1312389.950	1762283.598	2218392.410	2233930.324	2249468.237	2265006.151	2280544.064	2296081.978
MANITOBA	35469.499	71885.871	109249.116	147559.235	186816.227	189183.410	191550.593	193917.777	196284.960	198652.143
SASK NWT	37146.479	77201.710	120165.696	166038.434	214819.926	222091.809	229363.692	236635.576	243907.459	251179.342
ALBERTA	97190.169	195343.670	294460.503	394540.667	495584.163	497992.493	500400.822	502809.151	505217.481	507625.810
BRITISH COLUMBIA	87852.197	176555.619	266110.266	356516.138	447773.235	449901.297	452029.360	454157.422	456285.485	458413.547
YUKON	1059.746	2244.396	3553.950	4988.408	6547.770	6860.030	7172.290	7484.550	7796.809	8109.069
CANADA	1006695.652	2013391.304	3020086.957	4026782.609	5033478.261	5033478.261	5033478.261	5033478.261	5033478.261	5033478.261

METHANOL DEMAND
BASED ON PENETRATION OF THE M100 BLEND
REPLACING 5% OF DIESEL DEMAND IN 1989, 10% IN 1990, 15% IN 1991, 20% IN 1992, AND 25% IN 1993

NOTE: ALL VOLUMES IN THOUSANDS OF LITRES

METHANOL	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ATLANTIC	196235.217	419235.624	669507.647	947557.713	1253892.250	1324181.403	1395314.601	1467291.844	1540113.133	1613778.466
QUEBEC	234099.044	462814.953	685963.976	903362.362	1114826.362	1100143.520	1085154.427	1069859.083	1054257.488	1038349.642
ONTARIO	430944.812	885280.703	1363372.589	1865585.386	2392284.009	2453194.479	2514713.143	2576840.001	2639575.051	2702918.296
MANITOBA	88704.309	180512.934	275464.871	373599.116	474954.664	482975.426	491061.181	499211.930	507427.671	515708.405
SASK NWT	139153.045	281549.194	427215.270	576178.099	728464.502	736751.088	745082.380	753458.379	761879.085	770344.497
ALBERTA	271294.775	542049.793	812172.440	1081570.105	1350150.173	1348183.360	1346062.192	1343786.669	1341356.791	1338772.557
BRITISH COLUMBIA	214330.020	424058.101	629022.906	829063.097	1024017.339	1011436.912	998587.590	985469.374	972082.263	958426.257
YUKON	5562.573	11597.635	18113.497	25118.472	32620.871	33857.505	35107.991	36372.331	37650.524	38942.570
CANADA	1580323.797	3207098.938	4880833.198	6602034.350	8371210.170	8490723.693	8611083.507	8732289.611	8854342.005	8977240.690

APPENDIX F

THE ECONOMIC VALUE OF DISTILLER BY-PRODUCTS IN CANADA

(BY DR. K. K. KLEIN)

Appendix F

THE ECONOMIC VALUE OF DISTILLER'S BY-PRODUCTS IN CANADA

By

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Department of Economics, University of Lethbridge
and
Timothy J. Richards, Graduate Student,
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[The above study was completed in July, 1988, for the purpose of being included herein. What follows is a summary of the authors' findings as reported in the study. Any questions regarding the study can be addressed to its authors.]

F.1 Introduction

Ethanol net production costs vary considerably depending on the value obtained from selling its by-products. As ethanol production increases, the market prices of ethanol by-products are sure to decrease.

The purpose of this study is to determine what the sustainable range of market prices is for these by-products with supplies consistent with those implied by the ethanol production figures in the Regional Analysis section of this study (see Appendix E).

The second section of the paper will present a brief review of the ethanol production process along with a consideration of the chemical and nutritional characteristics of the by-products themselves. Section three details both the models used and the assumptions underlying their use. This section will also outline the methods used to obtain the results from the chosen data. The fourth section will present the results obtained from the manipulation of the above models, for each ethanol plant site considered. The final section will conclude and summarize the findings made in the paper.

F.2 Background

F.2.1 Processing

Ethanol can be produced from biological materials in two different ways; dry-milling or the beverage method, and wet milling. The process of converting grain into ethanol consists of five distinct steps. The first step in dry-milling is breaking up the grain kernels in order to expose the starch molecules. The next step, called saccharification, involves creating a solution containing 14 to 20 percent simple sugars. The starch solution created in the milling process must be cooked in order to "break the cell walls of the starch" (NRC 1981). Next, fermentation is the process which actually converts the simple sugars to ethanol and carbon dioxide. Since this does not produce a straight ethanol product, but a water-ethanol blend, distillation must occur in order to separate the two liquids. Basically, this step involves heating the ethanol-water mixture to 78^0 Celsius. As ethanol vaporizes at 78^0 Celsius and water at 100^0 Celsius, the ethanol can be recovered through the use of rectifying and recovery columns.

Wet milling involves a variation in the milling step of the general process outlined above. This step is broken down into several sub-steps, designed with the goal of producing a less fibrous, more pure starch solution from which to begin fermentation. Wet milling begins with the grains being steeped in a 5 percent sulphur dioxide solution in order to soften the grain. From there, the germ, fiber and gluten are removed in successive steps. Therefore, the main by-products of wet milling--corn gluten feed, corn gluten meal and corn oil--are all removed even before the fermentation process begins. Of 100 pounds of corn, this process removes 98.4 pounds of the dry matter before fermentation. Approximately 11 pounds of this would be in the form of corn gluten meal and about one-third of the grain can be recovered as corn gluten feed.

When dry-milling is used, the by-products are recovered as part of the slurry left at the bottom of the column used for distillation, or the "beer" column. This slurry, known as "whole stillage" is about 6 percent dry matter (NRC, 1981). Dry matter content is increased to 15 to 20 percent by screening, and then to 25 to 35 percent by centrifuging. The solids remaining can then be dried down to 90 percent solid matter and sold as distiller's dried grains; or they can be dried together with the thin stillage that is left after screening to produce distiller's dried grains plus solubles. Or the thin stillage, which is mainly composed of yeast residuals and other residues, can be dried by itself (down to about 30 percent dry matter) and sold as condensed distiller's solubles. The recovering of by-products is the fifth step in ethanol production.

Often, the whole stillage is sold on its own. This avoids the high energy costs associated with drying the product down to storable levels, but transportation and storage of the whole stillage is difficult and costly.

In the notation used in this study, the main ethanol by-products are corn gluten meal (CGM), corn gluten feed (CGF), condensed distiller's solubles (CDS), distiller's dried solubles (DDS), distiller's dried grains (DDG) and distiller's dried grains plus solubles (DDGS). As multiple varieties of dry-milling by-products exist depending upon the grain chosen, the exact type of by-product will be indicated by adding a prefix letter to that by-product, e.g., barley distiller's dried grains plus solubles becomes BDGS. Note, in the main text of the study, DDG is used as a generic term for all dry milling by-products.

F.2.2 Chemical Characteristics

Nutritionally, fermentation has the effect of removing all of the starch from the grain, but concentrating the remaining nutrients up to 300 percent (Berger, 1981 and Dong & Rasco, 1987). Berger also points out that, although the grain has been converted from a high energy to a high protein feedstuff, the high concentration of the remaining fibre means that the distiller's by-product still has over 90 percent of the base grain's energy. However, this fibre-based energy is only available to ruminating animals, such as cattle, due to their ability to process feed containing more cellulose. This ability derives from the unique microbial activity in ruminating animals.

Throughout the literature, there exists a wide discrepancy as to the actual chemical and nutritional breakdown of the various ethanol by-products. For this study, the standard National Research Council/National Academy of Sciences (1964, 1958, 1956) data has been used where possible, but other sources had to be used for missing pieces of data. Table F.1 presents the breakdown used in this study.

Numerous experiments have been conducted to determine the amino acid profiles of ethanol by-products. Unfortunately, the model used in this study does not incorporate amino acids, or, more particularly, lysine content, but this would be a fruitful avenue for future study.

F.2.3 Nutritional Characteristics

The value of distiller's by-products in the diets of swine and poultry is limited by two factors. First, monogastric animals lack the necessary intestinal microbes to digest the high fibre feeds. Second, they are sensitive to the feeds' poor amino acid profiles.

TABLE F.1

NUTRITIONAL COMPOSITION OF SELECTED ETHANOL BY-PRODUCTS

	Crude Protein (g/kg)	Digestible Energy (Mcal./kg)	Calcium (g/kg)	Phosphorus (g/Kg)	Dry Matter (kg DM/kg Feed)
CDDG[a,e]	25.3	3.48	1.0	4.0	.92
CDGS[a,e]	29.9	3.53	1.5	7.8	.92
BDDG[b,d]	27.7	2.80	1.5	7.6	.92
BDGS[c]	25.5	3.03	2.0	11.2	.92
WDDG[a]	36.3	3.19	1.1	5.4	.93
WDGS[a]	34.4	3.50	2.0	7.6	.93
RDDG[a]	24.1	2.37	1.4	4.4	.93
RDDS[a]	29.9	2.15	2.1	6.2	.91
CGM[b]	46.8	3.79	1.6	5.0	.91
CGF[b]	25.6	3.66	3.6	8.2	.90

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

LEGEND: Prefix notation as follows: C = corn, B = barley, W = wheat, R = rye.

[a] NRC/NAS, Joint U.S.-Canadian Tables of Feed Composition, 1956, 1958, and 1964.
[b] NRC/NAS, Nutrient Requirements of Beef Cattle, 1984.
[c] Castle and Watson, 1982.
[d] Northwest Economic Associates, 1981.
[e] Wu and String Fellow, 1982.

However, distiller's by-products are a good source of vitamin B and phosphorus which are otherwise expensive dietary supplements. Experiments have shown diets containing distiller's grains and fortified with amino acids to result in stimulated broiler growth (Jensen, 1982), and that the presence of DDGS in concentrations of up to 44 percent in the diets of swine have no deleterious effects on the gilts or their litters (A.H. Jensen, 1977).

Ruminants, on the other hand, are able to break down distiller's by-products because microbes resident in the rumen produce the enzyme cellulase, which aids in the digestion of cellulose. The ability of ruminants to convert non-protein nitrogen (NPN) into animal protein eliminates the problem posed by the poor amino acid profile of the ethanol by-products. However, the microbes also break down dietary protein to ammonia for the manufacture of microbial protein. Therefore a plant protein source that is able to avoid rumenal digestion, and is instead absorbed directly through the small intestine, is of high value as long as enough ammonia is present in the rumen for the purpose of meeting microbial protein requirements. Distiller's by-product protein bypasses the rumen with 60 percent of its mass, as compared to 30 percent for soybean meal. Ruminants have the ability to create microbial protein from NPN sources such as urea. As non-bypass protein sources serve the same purpose, they have values comparable to that of urea in the diets of ruminants.

Klopfenstein and Abrams (1981) demonstrated the value of bypass protein in terms of weight gain. Supplementing NPN beef diets with DDGS resulted in twice the weight gain as NPN diets supplemented with soybean meal containing the same mass of protein as the DDGS (see Table F.2). Firkins (1985) found corn DDG to have a feed gain ratio of 5.71, compared to 7.73 for soymeal diets.

Loosli (1952) found that feeding CDGS and CDS to lactating dairy cows resulted in higher milk yields than those from CGF/soybean meal diets. Schingoethe also recorded higher milk yields from diets with distiller's by-products.

The above findings seem to indicate that, in a fully penetrated market situation, beef and dairy cattle would dominate the demand for distiller's by-products. Therefore, non-ruminating animals are excluded from the analysis herein.

F.3 Methods and Models

The selection of sites for possible ethanol plants was based upon both the availability of wheat, barley, or corn for feedstock purposes, and the

TABLE F.2

EFFICIENCY OF DDG AND DDGS PROTEIN UTILIZATION BY BEEF CATTLE

Source	Average Daily Gain (lb.)	Gain[a] (lb.)	Supplemental Protein (lb.)	Gain/ Protein	Comparative Value[b] (lb.)
Urea	1.39	-	-	-	-
SBM	1.54	0.15	0.29	0.51	100
DDL	1.69	0.30	0.29	1.03	200
DDGS	1.66	0.27	0.29	0.93	180

SOURCE: Klopfenstein and Abrams, 1981.

[a] Gain above urea control.
[b] As a percentage of soymeal.

presence of beef or dairy cows to absorb the by-product (see Table F.3). The sites examined included only those with gasoline producing refining facilities in the immediate vicinity.

Although each site had sufficient cattle locally (with the exception of Taylor, British Columbia), it was found that some sites would be limited as to their choice of feedstock. Quebec's barley and corn acreages would be sufficient to support a commercial sized plant in Montreal, but the use of wheat would exhaust provincial supply. While Montreal and Oakville, Ontario would likely utilize corn feedstocks, Regina, Saskatchewan would use wheat, and Edmonton and Balzac, Alberta would likely choose barley. The fact that cattle are located in central and southern B.C. while grain is predominantly produced in the north of the province makes the possibility of a B.C. ethanol plant remote as long as ethanol economics are marginal. Athough a variety of possible feedstocks were entertained in the diet level analysis, only the most likely feedstock at each location was considered in the aggregate analysis.

Since many different forms of by-product exist, only a small proportion of them were selected for analysis. For the dry milling scenarios, the DGS from each feedstock were analyzed. The separation of the DDG from the dried solubles is not considered since all of the by-product is intended to be fed to the cattle in the final, integrated ethanol plant/refinery/feedlot agglomeration. Initial sensitivity analysis showed DDG not to differ significantly in feeding value from DGS at corresponding by-product price levels.

Both of the wet milling by-products (CGM and CGF) were analyzed in the Ontario beef diet model, but only CGM in the dairy diet. Likewise, only CGM was included in the analysis of wet milling by-products for the Montreal location.

F.3.1 Diet Level Analysis

In conducting the diet level demand analysis for ethanol by-products, two linear programming models were used. For the beef feedlot diet analysis, the Lethbridge beef feedlot model of B.S. Freeze (1988) was employed. A modified version of the dairy model used in Klein et al. (1986) was used for dairy diet analysis. These models generate diets which maximize the beef or milk producer's profit while meeting minimum nutritional requirements for the cattle. Therefore, profit maximizing producers should demand the feeds that are part of these diets.

TABLE F.3

FEED PRICES AT VARIOUS LOCATIONS: 1985-1988
($/t)

	Taylor/Edmonton		Balzac		Regina		Oakville		Montreal	
	1985	1988	1985	1988	1985	1988	1985	1988	1985	1988
Wheat	180.75	118.96	159.75	125.00	155.00	89.47	187.55	126.50	183.40	123.38
Oats	138.80	102.00	144.80	118.00	119.25	77.97	163.75	121.17	164.95	137.08
Barley	130.75	67.33	135.75	103.00	131.30	60.22	174.75	104.35	169.80	101.26
Corn	200.90	154.00	188.80	149.00	179.20	134.50	158.75	108.95	174.90	107.13
Soymeal	251.95	339.38	239.95	388.01	227.30	315.26	222.55	308.75	240.50	326.75
Rapemeal	150.00	210.00	133.10	252.00	159.80	200.00	146.00	206.60	138.80	227.04
Dehy. Alf.	155.00	148.00	163.50	141.00	144.00	127.00	165.00	160.00	199.00	166.00
Alfalfa	87.10	83.15	91.85	79.20	80.90	71.30	92.70	89.90	111.80	93.26
Silage	30.00	25.00	35.00	25.00	30.00	20.00	45.00	25.00	50.00	35.00

SOURCE: Grain Facts.

Prices from April 1988 were used in the analysis in order to present the current relative prices of the feeds (see Table F.3). April 1985 prices were also used for the sake of comparison. This was a time when base feeds were priced higher in relation to protein supplements (see Table F.4).

Demand curves were generated by varying only the price of the distiller's by-products, and calculating a new optimal diet at each price.

F.3.2 Aggregating Demand and Supply

Certain assumptions were necessary regarding market conditions in order to make the jump from analyzing optimal diets in terms of tonnes per head to analyzing aggregate supplies and demands for ethanol by-products.

On the supply side, the future demand for ethanol had to be studied. This section uses the demand for ethanol as determined by the penetration of the E10 blend, as presented in Appendix E. Ethanol yields were set at 350 litres per tonne from all feedstocks to reflect some inefficiency in conversion. A by-product yield of 11 weight percent was attributed to the recovery of corn gluten meal, and 33 weight percent for all other by-products. Using these figures, the Regional Analysis projects the supply of ethanol and by-products, as well as the required tonnage of feedstock necessary to support those supplies.

Demand per head and total head were assumed constant over the time frame of the analysis. A crude estimate of provincial demand was attained by taking the sum of the products of each type of animal (beef or dairy cattle) and the amount of ethanol by-products in the optimal diet per head at each price. As mentioned earlier, non-ruminating animals were omitted from the study.

Separate markets were then defined for the Canadian ethanol by-product industry. The assumptions herein are that British Columbia demand is met by the Taylor plant, that Alberta is supplied by plants in both Edmonton and Balzac, that the Regina plant serves all of Saskatchewan and Manitoba, that the Oakville plant supplies Ontario, and that all points east are served by the Montreal plant. It is recognized however, that current by-product production from the Mohawk plant in Minnedosa, Manitoba would absorb some of the Saskatchewan/Manitoba market.

Although it would have an effect on actual market prices, personal feed preference was not considered in the analysis. The demand calculations are based strictly on least cost diets. Consideration of feedback effects on

TABLE F.4

1985-1988 CALGARY FEED PRICES
($/t)

Date	April 1985		April 1986		April 1987		April 1988		June 1988	
	Price	Ratio[a]	Price	Ratio[a]	Price	Ratio[a]	Price	Ratio[a]	Price	Ratio 9
Feed										
Wheat	159.75		125.50		79.50		125.00		138.60	
Oats	144.80	0.91	124.30	0.99	89.00	1.12	118.00	0.944	137.50	0.992
Barley	135.75	0.85	92.00	0.73	76.00	0.96	103.00	0.824	85.00	0.613
Corn	188.80	1.18	161.00	1.28	148.00	1.86	149.00	1.190	175.00	1.263
Soymeal	239.95	1.50	305.30	2.43	293.70	3.69	388.00	3.100	448.00	3.209
Rapemeal	133.10	0.83	205.70	1.64	153.00	1.92	252.00	2.020	295.00	2.128
Dehy. Alf.	163.50	1.02	159.00	1.27	165.00	2.05	141.00	1.130	135.00	0.974
Alfalfa[b]	91.85						79.20		75.00	
Cereal[b]	35.88						25.00			

SOURCE: Grain Facts, Livestock Feed Board of Canada.

[a] Ratio of feed price to wheat price.
[b] Estimated based on past relationships.

grain prices was omitted, but would most likely lead to increased feed grain prices and, thus, higher ethanol by-product prices.

F.4 Results

F.4.1 Taylor and Edmonton

Barley is the most plentiful of feed grains in Northern Alberta. Therefore, using Northern Alberta feed prices, BDGS was the by-product included with conventional feeds in optimal diet analysis for both beef and dairy cattle. WDGS were also analyzed in the dairy diets.

The dairy results show by-products in the optimal diet at higher demand per head than do the beef results (see Table F.5). This is consistent with intuition as lactating cows have the additional nutritional requirements accounted for by the production of milk.

Higher by-product demand was recorded under the 1985 relative price scenario (high base feed prices) than that of 1988 (high protein supplement prices).

F.4.2 Balzac

Using Calgary feed prices, WDGS and BDGS were used in the beef cattle diet analysis. Again, 1988 prices were found to be less conducive to by-product demand (see Table F.6).

Additional analysis revealed DDG products to be unable to match the quantities demanded per head that their respective products with solubles were able to attain. This can be attributed to the higher levels of calcium, phosphorus, and protein retained in the solubles.

F.4.3 Regina

Wheat is the predominant grain crop in the Regina area. Therefore, using Regina feed wheat prices, the demand for WDGS was analysed.

Regina grain prices have historically differed only slightly from Saskatoon prices and, as a result, the Regina analysis can be generalized to other locations in Saskatchewan where barley is more prevalent. Thus, BDGS was also analysed. The results of the analysis appear in Table F.7.

In addition to April prices from 1985 and 1988, the most current (June 15, 1988) Regina prices were also utilized. Due to widespread drought, competitive grain was priced higher than normal and protein supplements such as rapemeal and soymeal were priced high relative to the base grains.

TABLE F.5

TAYLOR AND EDMONTON BEEF AND DAIRY DIETS

Beef Diets - BDGS		Beef Diets - WDGS				Dairy Diets - BDGS			
1985		1985		1988		1985		1988	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.47	0	1.52	0	1.47	0	2.61	0	1.52
105	1.09	120	1.17	50	0.37	110	1.84	70	0.15
110	0.66	125	0.92	60	0.18	115	1.11	80	0.07
120	0.12	135	0.12	70	0.10	120	0.85	150	0.03
140	0.05	160	0.01	115	0.04	125	0.33	160	0.02
160	0.00	170	0.00	125	0.02	160	0.05	170	0.01
				140	0.00	210	0.00	180	0.00

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

TABLE F.6

BALZAC BEEF AND DAIRY DIETS

Beef Diets - BDGS				Beef Diets - WDGS			
1985		1988		1985		1988	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.47	0	1.47	0	1.52	0	1.52
110	0.97	88	0.37	130	1.05	105	0.42
115	0.57	90	0.18	135	0.80	110	0.11
125	0.12	95	0.12	140	0.12	120	0.03
130	0.09	110	0.02	150	0.10	130	0.02
150	0.00	120	0.00	160	0.00	140	0.00
						200	0.04
						210	0.00

Beef Diets - BDDG		Beef Diets - WDDG		Dairy Diets - BDGS	
1988		1988		1985	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.79	0	1.79	0	2.64
40	1.68	95	0.14	100	1.40
50	1.11	110	0.03	105	1.35
80	0.73	120	0.02	135	1.12
85	0.16	130	0.00	150	0.68
90	0.12			155	0.33
				200	0.02
				210	0.00

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

TABLE F.7

REGINA BEEF AND DAIRY DIETS

Beef - BDGS				Beef - WDGS				Dairy - WDGS	
1985		1988		1985		1988		1988	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.47	0	1.47	0	1.52	0	1.52	0	4.41
95	1.09	40	0.38	110	1.17	60	0.76	115	3.38
100	0.66	60	0.10	120	0.92	70	0.18	135	0.97
125	0.12	95	0.04	135	0.12	80	0.07	190	0.62
145	0.05	105	0.02	160	0.01	125	0.03	230	0.36
160	0.00	120	0.00	170	0.00	140	0.02	240	0.33
						160	0.00	300	0.00

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

Because rapemeal and soymeal were priced at two-year highs in the June case, they never entered the optimal diet. This is a highly optimistic scenario for the demand for ethanol by-products, resulting in high by-product demand per head.

To examine the effects of changing grain and beef prices, sensitivity analyses were performed on the Regina location. Varying beef prices seemed only to affect profit per head. The optimal beef cattle diet was virtually insensitive to these changes. On the other hand, the diet was extremely sensitive to varying barley prices.

F.4.4 Oakville

The quality of soil in southern Ontario allows for the consideration of barley, wheat, and corn dry milled by-products on the feed market. Beef results showed WDGS to command higher demand per head than BDGS, followed by CDGS at each price. CGM was revealed to experience a higher demand than CGF at each price and, in general, these wet milled by-products formed a greater portion of the optimal beef diet than the dry milled by-products at each price. The dairy model yielded comparable demand for CDGs and WDGS, both lower than that for CGM (see Tables F.8, F.9 and F.10).

F.4.5 Montreal

The existence of corn as a potential feedstock again allowed for the analysis of wet milled by-product demand. Ethanol production by wet milling yields CGM and CGF as by-products, along with corn oil and waste. BDGS was also analyzed because feed transportation assistance schemes cause the region's barley supply to be artificially inflated.

Again, it was found that if protein supplements are priced relatively low, they compete well with ethanol by-products (see Tables F.11 and F.12).

F.5 Aggregate Analysis

Given the supplies of by-product generated by the network of six proposed ethanol plants across Canada working to satisfy the projected demand for ethanol, as well as estimates of the provincial market demands obtained from the optimal diet analysis, cattle counts, and grain supplies (see Table F.13), an estimate of the market price that each by-product will be able to sustain in each region was reached (see Table F.14).

The analysis indicated that an average price of \$160-\$170 per tonne would be sustainable for most products in Canada, with actual market

TABLE F.8

OAKVILLE BEEF DIETS: DRY MILLING BY-PRODUCTS

Beef - BDGS				Beef - WDGS				Beef- CDGS			
1985		1988		1985		1988		1985		1988	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.47	0	1.47	0	1.52	0	1.52	0	1.47	0	1.47
110	1.09	85	0.37	130	1.17	105	0.76	130	1.13	105	0.63
115	0.66	90	0.18	135	0.92	110	0.15	135	0.87	110	0.16
140	0.59	105	0.10	150	0.79	125	0.07	150	0.78	125	0.09
145	0.39	110	0.04	160	0.12	135	0.03	160	0.18	130	0.04
150	0.12	120	0.02	190	0.00	150	0.02	180	0.10	140	0.02
165	0.10	135	0.00			170	0.00	190	0.09	160	0.00
170	0.08							200	0.00		
180	0.00										

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

TABLE F.9

OAKVILLE BEEF DIETS: WET MILLING BY-PRODUCTS

Beef - CGM				Beef - CGF[a]			
1985		1988		1985		1988	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.51	0	1.51	0	1.63	0	1.51
140	1.23	120	0.12	20	1.51	110	0.94
145	0.69	135	0.04	135	1.17	115	0.12
150	0.67	160	0.02	140	0.77	130	0.05
165	0.61	170	0.00	160	0.68	140	0.00
175	0.40			170	0.00		
220	0.00						

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

[a] Corn gluten feed.

TABLE F.10

OAKVILLE DAIRY DIETS: DRY AND WET MILLING BY-PRODUCTS

Dairy CDGS		Dairy WDGS		Dairy CGM	
1985		1985		1985	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	4.27	0	4.41	0	4.42
130	3.27	130	3.38	140	3.59
135	1.31	135	1.09	145	1.11
145	0.81	145	0.67	150	0.73
155	0.33	155	0.39	165	0.47
175	0.14	180	0.12	180	0.10
210	0.00	220	0.00	230	0.00

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

TABLE F.11

MONTREAL BEEF DIETS

Beef - BDGS				Beef - CDGS[a]				Beef- CGM[b]			
1985		1988		1985		1988		1985		1988	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	1.47	0	1.47	0	1.47	0	1.47	0	1.51	0	1.51
120	1.36	80	0.37	145	1.37	100	0.63	160	1.43	115	0.12
130	1.18	90	0.18	155	0.85	105	0.16	170	1.29	130	0.04
135	0.80	100	0.10	160	0.66	120	0.09	175	0.95	170	0.00
140	0.49	120	0.04	180	0.18	140	0.04	180	0.52		
160	0.09	130	0.02	190	0.09	150	0.02	200	0.09		
185	0.00	145	0.00	210	0.00	170	0.00	240	0.00		

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

[a] Corn distillers' dried grains with solubles.
[b] Corn gluten meal.

TABLE F.12

MONTREAL DAIRY DIETS

Dairy - CDGS		Dairy - CGM	
1985		1985	
Price ($/t)	Quantity (t/head)	Price ($/t)	Quantity (t/head)
0	4.27	0	4.41
130	2.51	150	1.47
140	2.09	160	1.22
145	1.42	170	0.83
165	0.60	210	0.41
170	0.31	220	0.09
190	0.14	250	0.00
220	0.00		

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

TABLE F.13

PROVINCIAL DAIRY HERD, BEEF HERD, AND GRAIN ACREAGE
(10^3 head, 10^3 acres)

	B.C.	Alta.	Sask.	Man.	Ont.	Que.
Cattle:						
Dairy	75	124	5	65	475	578
Beef	215	1,322	766	378	344	163
Grain:						
Barley	158	5,568	3,579	1,568	576	402
Wheat	99	7,602	21,660	4,926	717	132
Corn	-	-	-	32	1,829	1,155

SOURCE: Canada, Census Canada, Agriculture 1986, Supply and Services, Ottawa.

TABLE F.14

ETHANOL BY-PRODUCT DEMAND SCHEDULES
(10^3 tonnes)

Price ($/tonne)	B.C.: BDGS	Alta.: BDGS	Sask.: WDGS	Ont.: CDGS	Ont.: WDGS	Ont.: CGM	Que.: CDGS	Que.: CGM
300			0					
250							0	
240			39					54
230			43			0		
220					0	45	0	63
210	0	0		0		62	80	244
200		5		66				489
190			74	95	57		94	
180				101	98	84	199	564
175				127		362		634
170			115				288	690
165				217		334	955	
160	4	24	126		197		930	938
155		120		423	426		960	
150		140		652	588	577		1092
145				684	635	764	1046	
140						2128	1448	
135		229	252	922	834			
130		243		1941	2008		1691	
125	51	263						
120	90	593	1451					
115	225	966	1737					
110	280	1273	1858					
105		2198						
100		2200						
0	512	2277	2259	2534	2618	2619	2708	2801

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988).

TABLE F.15

ETHANOL BY-PRODUCT SUPPLIES AND MARKET CLEARING PRICES

	Year	Supply[a] (10^3 tonnes)	Price ($/tonne)
BC: BDGS	1989	14	125-160
	1991	43	125-160
	1993	72	120-125
Alberta: BDGS	1989	16	160-200
	1991	47	155-160
	1993	79	155-160
Saskatchewan: WDGS	1989	11	240-300
	1991	37	240-300
	1993	64	190-230
Ontario: CDGS	1989	69	190-200
	1991	210	165-175
	1993	355	155-165
Ontario: WDGS	1989	69	180-190
	1991	210	155-160
	1993	355	155-160
Ontario: CGM	1989	23	220-230
	1991	70	180-210
	1993	118	175-180
Quebec: CDGS	1989	51	210-220
	1991	146	180-190
	1993	234	170-180
Quebec: CGM	1989	17	240-250
	1991	49	240-250
	1993	78	210-220

SOURCE: K. K. Klein and T. J. Richards, "The Economic Value of Distillers' By-Products in Canada," paper prepared for the Canadian Energy Research Institute, Calgary, Alberta (Lethbridge, Alberta: University of Lethbridge, Dept. of Economics, July 1988), CERI.

[a] These figures differ from those that appear in Klein et al. due to changes that were implemented in the regional analysis (Appendix E) that resulted in a larger by-product supply.

prices varying by region and by product (see Table F.15).[1] Generally, wheat and corn dry milled by-products outperform barley by-products. Wet milled by-products would seem to command higher prices than the dry milled feeds. CGM tends to attract higher market prices because of its low yield from corn. At only one-third the by-product yield (11 weight percent as compared to 33 weight percent for other by-products), the feed avoids flooding the market, unlike the other by-products.

The distiller's grains experience higher demand levels at higher energy feed prices. Since the bypass protein feature of distiller's by-products enables not only more efficient use of feed protein, but also of the energy content of the feeds (Bailey, 1988), the by-products also compete with grains on an energy basis. This implies that although the protein efficiency causes dairy demand to fall out at a higher price, high energy users will derive more value than previously thought from distiller's grains.

Consistent with the analysis of Dietert (1987), the predominant market for distiller's by-products seems to be as an energy source, which would limit its value to the $150-170 per tonne range. Only when other protein sources have very high prices do the by-products tend to be valued as protein feed and achieve market values in excess of $200-220 per tonne.

A few other general conclusions were derived. The relative feeding value of distiller's by-products will be higher to dairy cows than to beef cows by anywhere from 10 percent to over 50 percent in some cases. Furthermore, distiller's by-products will sell at a larger premium to their associated feedstock the greater is the gap between feed grain and protein supplement market prices. This fact is due to distiller's feeds value being, principally, as a protein feed. Also, wet milling by-products can support a higher feeding value than can dry milling by-products. In addition, corn by-products tend to have a higher relative feeding value than other products, providing that corn is a major feed in that location. Finally, the locations that offer a greater selection of potential feedstocks, such as Regina, Oakville and Montreal, tend to promise a greater possibility for high by-product values than do the locations where feedstock choice is limited: such as Taylor, Balzac and Edmonton.

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[1] This statement has been changed from that which appears in Klein et al. due to changes that were implemented in the regional analysis (Appendix E) that resulted in a larger by-product supply. The actual value that appears in the study is $170 per tonne.

APPENDIX G

GLOSSARY

Appendix G

GLOSSARY

ALCOHOL: One of a large series of organic compounds; some occur naturally but most are manufactured. Formed by replacing one or more hydrogen atoms in a hydrocarbon molecule with a hydroxyl group.

ALCOHOL CONTAINING FUEL: Fuel containing 1-100 vol% alcohol, (i.e., blend fuels as well as fuel alcohols).

ALDEHYDE: One of a series of chemical compounds, many toxic, formed by incomplete oxidation of alcohols (e.g., formaldehyde is made from methanol).

ANTIKNOCK: Resistance of motor fuel to the tendency to knock (see Knocking).

AROMATICS: Hydrocarbons characterized by unsaturated ring structures of carbon atoms. Commercial petroleum aromatics are benzene, toluene and xylene (BTX).

BIOMASS: Material of plant origin, including agricultural wastes, wood and animal manure.

BLEND FUEL: Fuel containing blend of gasoline and 1-60 percent alcohol.

BUTANE: Highly flammable, volatile, gaseous hydrocarbon (C_4H_{10}) that is extracted from natural gas or produced by cracking petroleum. Used as a blending compound to increase the vapour pressure of gasoline and promote cold starting. Exists in two different molecular forms or isomers; in normal butane (n-butane), the four carbon atoms are arranged in a straight line, but in isobutane they form a branched chain. The calorific value of n-butane is higher.

CARBON MONOXIDE: A colourless, odourless, toxic gas composed of equal parts of carbon and oxygen. Produced by partial combustion (oxidation) of hydrocarbon fuels.

CATALYST: A substance that helps to initiate a chemical reaction and enables it to proceed under less severe conditions (for example, at a lower temperature or pressure), but remains unchanged itself.

CATALYTIC CONVERTER: A device fitted to the exhaust system of a motor vehicle to reduce the levels of hydrocarbons, carbon monoxide and nitrogen oxides in the exhaust gas. Various metals and alloys, including platinum, copper and nickel, can be used. Since tetraethyl lead poisons the catalyst, lead-free gasoline must be used.

CATALYTIC REFORMING: A refining process using controlled heat and pressure with catalysts to rearrange certain hydrocarbon molecules, thereby converting paraffinic and naphthenic type hydrocarbons (e.g., low-octane gasoline boiling range fractions) into petrochemical feedstocks and higher octane stocks suitable for blending into finished gasoline. Catalytic reforming is reported in two categories. They are:

Low Pressure: A processing unit operating at less than 225 pounds per square inch gauge (PSIG) measured at the outlet separator.

High Pressure: A processing unit operating at either equal to or greater than 225 pounds per square inch gauge (PSIG) measured at the outlet separator.

CELLULOSE: Complex fibrous carbohydrate that performs a supporting function in plant tissue. Molecule consists of glucose units linked together in chains, with the formula $(C_6H_{10}O_5)n$, where n = 2000 to 4000. The most abundant naturally occurring organic compound. Can be broken down by hydrolysis into simpler carbohydrates like starches and sugars.

COMPRESSION RATIO: Ratio of the volume of gas within the cylinder of a vehicle engine before compression to the volume after the gas has been fully compressed by the piston. If the CR is too high, knocking occurs. In a modern automobile engine, the CR is about 9:1.

CORROSION: Erosion of a metal surface caused by chemical reaction of the metal with substances in contact with it.

COSOLVENT: Chemical compound with good solvent properties that is added to a methanol-gasoline blend to prevent phase separation, reduce corrosion and improve lubrication.

DIESEL FUEL: High-grade fuel oil suitable for use in compression ignition engines. Available in different grades; regular has a cetane number of 40-45 and premium of 45-50.

DISTILLATION: Process of heating a liquid to the boiling point and collecting and condensing the resulting vapour.

DUAL-FUEL CARBURETION SYSTEM: A vehicle system equipped to operate on two different fuels, (e.g., diesel and methanol).

ENZYME: Type of protein found in living matter; acts as a catalyst in chemical reactions occurring within the cells. Each enzyme is specific to a particular reaction.

ETHANOL: Colourless, volatile, flammable liquid with the formula C_2H_5OH. Used as a fuel, as a reagent in many industrial processes, and in intoxicating beverages.

FERMENTATION: Breakdown of a sugar into ethanol and carbon dioxide by the action of yeasts or bacteria.

FUEL-AIR MIXTURE: Fuel and air supplied to an engine which, when burned together, expand and provide propulsion.

FUEL-AIR RATIO: Ratio of the weight of fuel to air that is required for consistent ignition in a vehicle engine.

FUEL ALCOHOL/FUEL METHANOL/FUEL ETHANOL: Fuel containing minimum 85 vol% alcohol/methanol/ethanol, (e.g., M85, M100), ("fuel alcohol" is sometimes referred to as "alcohol fuel").

GASIFICATION: Production of methane from coal or biomass by heating the feedstock to high temperatures under high pressure in a restricted amount of oxygen.

GASOHOL: A blend of 10 percent ethanol with gasoline.

GASOLINE: Refined mixture of volatile, petroleum-derived hydrocarbon liquids with octane numbers ranging from 60 to above 100; used as a fuel for spark ignition engines.

HEATING VALUE: Amount of heat released during complete oxidation (combustion) of a given amount of a fuel at constant pressure. Also called heat of combustion.

HIGH-LEVEL BLEND: Fuel for purpose-built or retrofitted cars and containing 10-60 vol% alcohol (e.g., E20).

HYDROCARBON: One of a very large series of chemical compounds, consisting solely of carbon and hydrogen atoms, which form the basis of all petroleum products. Those with few carbon atoms are gases and those with many are solids.

HYDROLYSIS: Chemical reaction of water with another compound; the molecules of both are split, the two parts of the water molecule each combining with part of the molecule from the other compound.

ISOPROPANOL: Colourless liquid in the alcohol series, with the formula $(CH_3)_2$ CHOH, commonly used as a cosolvent in methanol-gasoline blends.

ISOBUTANOL: A four-carbon alcohol often used as a cosolvent in methanol-gasoline blends.

ISOMERIZATION: A refining process which alters the fundamental arrangement of atoms in the molecule without adding or removing anything from the original material. Used to convert normal butane into isobutane, (C4), an alkylation process feedstock, and normal pentane and hexane into isopentane, (C5), and isohexane, (C6), high-octane gasoline components.

KNOCKING: Pinging sound in a spark ignition engine caused by the fuel-air mixture self-igniting before the spark is passed at the spark plug; can lead to engine damage. Prevented by using a higher octane fuel.

LIGNIN: Organic compound that supports plant tissue. Wood is 25 to 35 percent lignin. Binds cellulose fibres together and therefore interferes with the breakdown of cellulose into sugars during hydrolysis.

LOW-LEVEL BLEND: Fuel usable in existing cars and containing max 10 vol% alcohol (e.g., M3, E10).

METHANOL: Colourless, toxic liquid with the formula CH_3OH; the simplest of the alcohol series. Also called methyl alcohol.

METHYL TERTIARY BUTYL ETHER: Liquid additive used to increase the octane number of unleaded gasoline.

NITROGEN OXIDES: Various gaseous combinations of nitrogen and oxygen atoms produced by burning fuels and therefore found in exhaust emissions. Usually abbreviated as NO_x. All are toxic except nitrogen dioxide.

OCTANE: Flammable, petroleum-derived hydrocarbon (C_8H_{18}) that exists in many molecular forms or isomers.

OCTANE ENHANCER: Additive that raises the octane number of a fuel.

OCTANE NUMBER: An arbitrary value that indicates the antiknock quality, or grade, of a gasoline, (i.e., provides a measure of the resistance of the fuel to premature ignition). Iso-octane (octane number 100) is added to n-heptane (octane number 0) to produce a mixture with the same knocking characteristics as the gasoline blend being tested. The proportion of iso-octane in the mixture indicates the octane number of the gasoline blend. Available gasoline blends usually range in octane number from 92 to 100.

OCTANE RATING: See Octane Number.

OLEFIN: One of a group of manufactured hydrocarbons that are characterized chemically by a double bond between two hydrogen atoms, making them very reactive and therefore useful industrially. Ethylene and propylene belong to this group.

OXYGENATES: Oxygenates include both alcohols and ethers used as octane boosting additives for gasoline (e.g., ethanol, methyl tertiary butyl ether). When these compounds are added to gasoline in small amounts, a blend known as "oxygenated gasoline" results.

REFINERY BLENDING: Mixing of an alcohol fuel with gasoline at the refinery for distribution as a blended fuel.

SPARK IGNITION ENGINE: A piston engine that relies on a spark plug within each engine cylinder to ignite the fuels. Gasoline-powered engines are of this type.

SPARK PLUG: Device fitted onto the cylinder of a spark ignition engine that contains a pair of electrodes between which a spark passes to ignite the fuel.

STARCH: A white odourless, tasteless gramular carbohydrate $(C_6H_{10}O_5)_x$ that is the chief storage form of carbohydrates in plants. It can be broken down fairly readily by enzymes or acids to produce fermentable sugars for ethanol production.

STEAM REFORMING: Production of synthesis gas by passing methane or other hydrocarbon vapour over a catalyst at high temperature.

STOICHIOMETRIC RATIO: Ideal fuel-air mixture for an engine (i.e., the fuel is completely oxidized and no excess air remains).

STRIPPER COLUMN: Pressure vessel for purifying methanol by removing carbon dioxide and heavy hydrocarbons.

SUGAR: Simple type of carbohydrate found in plants. Can be directly fermented to produce ethanol.

SURFACTANT: Liquid added to an emulsion to ensure that the liquids do not separate out.

TERTIARY BUTANOL: Type of alcohol commonly used as a cosolvent in methanol-gasoline blends.

UNLEADED GASOLINE: Gasoline blend containing sufficient high-octane hydrocarbons to ensure a high octane number without the use of lead additives.

VOLATILE: Readily evaporates at relatively low temperatures.

VOLATILITY: Measure of the tendency of a fuel to change from a liquid to a vapour at a specified temperature and pressure.

XYLENE: An aromatic hydrocarbon, $(C_6H_4Y(CH_3)_2)$, produced in petroleum refining (cracking) processes. One important use is as a solvent in the manufacture of paints. Along with toluene, it is a key ingredient in unleaded gasoline.

SOURCES: (1) Alcohol and alcohol blends as motor fuels, Vol. I. Prepared by The Swedish Motor Fuel Technology Co. (SDAB) for the International Energy Agency, (Stockholm 1986), (2) Petroleum Supply Monthly published by the U.S. Energy Information Administration, Washington, D.C, Nov. 1987, and (3) Future Transportation Fuels, Alcohol Fuels, Ministry of Supply and Services Canada, 1986.

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